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A SHORT SUMMARY OF OUR KNOWLEDGE OF THE FRIT-FLY.

BY J. E. COLLIN, F.E.S.

(*Food Production Department.*)

Communicated by Mr J. C. F. Fryer.

THE fact that very extensive damage to corn crops throughout Northern and Central Europe may be the work of the frit-fly has been recognised for the past century and a half, the first record being published by Linné in 1750, but in the British Isles it is in only comparatively recent years that public attention has been directed to the losses caused by these depredations, though in many parts of the country the crops (especially of oats) are always liable to be attacked, and in some years the damage done is enormous.

A very large amount of literature on the subject has been published, chiefly continental, and much of it appears in periodicals or reports of only a limited circulation. In the following pages an attempt is made to collate all the more important facts concerning the frit-fly contained in such of this literature as has been accessible, with a view to arriving at some idea of what has been discovered up to the present time of the life history, and methods of combating the attacks, of this destructive little insect. Much of the information contained in Russian publications has been extracted from *The Review of Applied Entomology*.

On the Continent two species of *Oscinis* (*O. frit* and *O. pusilla*) are considered to be responsible for frit-fly attacks, but as the *O. pusilla* Meig. which several economic entomologists have professed to recognise is certainly not the form or species described by Meigen under that name, and as most authorities of the present day on Diptera consider *O. frit* to be a species exhibiting very considerable variation in the colour of its legs and in its size, reference to any such varieties (including *O. pusilla*) are incorporated in the present summary.

DISTRIBUTION.

Frit-fly damage has been recorded from Norway, Sweden, Denmark, Finland, practically all Russia, Bulgaria, Austria, Germany, Holland, France, and the British Isles; while attacks by the larvae of Oscinids on cereal crops (though the species of *Oscinis* attacking are supposed to be different) have been recorded from Canada (Criddle, 1916) and Minnesota, U.S.A. (Washburn, 1905).

Distribution in England and Wales.

Roughly speaking, the species is very troublesome in the whole of the south of England from Cornwall to Kent, in the Eastern Counties (except in the Fen District), and up through the counties between Wales and the Midlands to Lancashire and Yorkshire, with a few records from Northumberland. It appears to be especially destructive in the counties bordering on the Thames and the Severn, and in Hampshire, Dorset, E. Devon, and the Isle of Wight. In Wales it has been noted as a pest from counties on the English border such as Glamorgan, Radnorshire and Flintshire, and it has been recorded as doing damage in Ireland and Scotland.

EXTENT OF DAMAGE.

The following few quotations from published and unpublished correspondents' reports will give some idea of the damage that may be caused by *frit* attacks.

"A field planted in the autumn with two bushels per acre, so entirely eaten the following spring as not to have left one healthy plant in a yard. They have robbed me of about fifteen bushels per acre on nearly fifty acres of fallow wheat." (Creese, Teddington near Tewkesbury, *vide* Ormerod, Report for 1881.)

"Nothing could have been more luxuriant than our Oat-crop at an early stage, but at present the whole aspect has changed, the fields being one mass of patches, getting worse and worse daily." (Bulteel, Ivybridge, S. Devon, *vide* Ormerod, Report for 1888.)

"The crop [of oats] came up and looked well until the latter part of May, what promised to be a heavy crop will only be a third." (Stick, St Columb, Cornwall, *vide* Ormerod, Report for 1888.)

"A very large area [of oats] in this part of the country has suffered." "The crop is practically destroyed except for hay." "The damage is quite appalling—90 % of crop gone." (McCracken, Royal Agricultural College, Cirencester, *vide* Ormerod, Report for 1888.)

Letter from a Gloucestershire farmer in 1917: "Two of the [last] ten years I lost the entire crop, and the remaining eight I lost more than half, entirely through

Frit-fly... the loss to the country I consider is very much greater than either Anthrax, Sheep-Scab or Swine Fever. In 1913, 1914 numbers of farmers in the district have turned stock into their oat fields just before harvest as they found it was not worth cutting."

Letter from a Wiltshire farmer in 1917: "I have had my crop [of oats] depreciated at least a third on several occasions in recent years, making a loss of £320 on the oat-crop alone by Frit-fly, and the sample is always of an inferior quality which is much more noticeable in white oats."

"All growth practically stopped in a field of barley in Shropshire sown May 4th." (Roebuck, June 1917.)

"Three acres of spring wheat in S. Shropshire totally destroyed by Frit-fly." (Roebuck, July 1917.)

"Spring wheat sown end of April totally destroyed in Radnorshire." (Roebuck, July 1917.)

"Winchester, oats put in late, the whole would have been ploughed up but for clover, no oats at all." (Theobald, June 1917.)

"Frit-fly attacks during the last five or six years have been so general and destructive in the county that many farmers have stopped growing the crop." (Bland, June 1917.)

In addition to the damage to the young oat plants, subsequent damage to the corn in the panicles is often very great, probably much greater than is generally realised. The following may be taken as a sample of the result of an attack of this nature:

In Wiltshire in 1917 five acres were sown at the end of April with Scotch seed of "Abundance" oat bought direct from Garton's. The yield of this field was 40 sacks of corn, very light in weight. An examination of an undressed sample of the corn gave the following result:

Grains examined	*Obvious frit damage*	*No grain or very light grain, probably largely due to "frit"*	*Sound corn*
358	74	70	214

The Returns published by the Board of Agriculture of the average yield of oats in England for the years 1910–1915 are instructive because they include the year 1912 when frit-fly attacks were exceptionally bad (*vide Journ. Board Agric.* Sept. 1912, p. 482) and a comparison may be made with other years when frit-fly damage was normal[1].

[1] To arrive at the normal annual loss due to frit-fly one must take as a basis the average yield per acre of oats when free from frit-fly attacks, a figure difficult to arrive at as oats have been known to yield anything up to 120 bushels per acre. A yield of 60 bushels is considered by agricultural experts a satisfactory crop, and one of 80 bushels a very good crop. Taking 50 bushels per acre as a standard for England one arrives at an average annual loss of about 8 bushels per acre for the ten years 1901–1910, being equivalent to 16 per cent. or nearly 15,000,000 bushels per annum.

Average yield in bushels per acre of Oats in England.

1910	41·87	1913	38·50
1911	39·03	1914	40·01
1912	35·56	1915	40·52

Average yield in England for ten years 1901–1910 = 42·07.

Taking the ten year average to 1910 as a basis it will be seen that in 1912 when frit-fly attacks were very bad the yield was reduced by no less than 6½ bushels per acre and as the acreage under oats that year was 1,865,569 this would represent a loss of 12,126,198 bushels.

PLANTS ATTACKED.

Rye, oats, barley, wheat, maize, and various grasses (*Bromus* sp., *Poa annua*, *Poa pratensis*, *Triticum repens*, *Triticum cristatum*, *Phleum pratense*, *Alopecurus pratensis*, *Milium effusum*, *Lolium perenne*, *Festuca pratensis*, *Avena flavescens*, *Arrhenatherum avenaceum* and its var. *bulbosum*). In England spring oats are chiefly attacked, though attacks have been recorded on winter oats, winter and spring wheat, barley, rye and grasses. Attacks are most common (or most noticeable) on the young plants, and these plants must not be far advanced in growth (Ritzema Bos, 1891); but the larvae of the third brood will feed in the panicles of oats still hidden in the sheath (*Board of Agric. Rep. on Inj. Ins. in* 1892), or in the young corn in the panicle, more rarely so far as the British Isles are concerned in the ears of barley (*vide* under "Imago" and Theobald (1906), and *Text Book Agric. Zool.* 1899), while the only records traced of larvae living in the ears of wheat are the breeding of *O. granarius* from a wheat kernel by Curtis (*Farm Insects*) and Carpenter's record (1909) of *O. frit* received "early in October from Queen's County where they had been found on newly threshed wheat." According to Ritzema Bos (*Zeitschr. f. Pflanzenkr.* 1, 1891, p. 347) the females of the second brood will only lay their eggs on the blossoming oats, and when oats have been attacked in the spring the flies produced from the larvae making this attack are very rarely on the wing in time to find the oats in blossom, and consequently have to oviposit on wild grasses[1]. It would appear that the flies when able to choose between oats and barley prefer the oats, for Miss Ormerod in her Report for 1888 stated that where "dredge corn" (barley and oats mixed) is planted, the maggot

[1] This was not the case in experiments carried out by the Department in 1918, late sown oats growing in the same field as those sown earlier being badly attacked both in the young plant and in the ripening grain.

will attack the oats and leave the barley; again, in the same Report, she quoted a letter to the effect that oats, drilled about the middle of April on part of a field after roots fed off by sheep, were badly attacked; the other part of the field being planted with barley did not appear to have been attacked. The same discrimination on the part of the fly was noted in Part II of the *Annual Report of Intelligence Division of the Board of Agriculture* (1911). Ritzema Bos (1894) quoted a case where it appeared that the fly preferred oats to wheat.

On the Continent, the larvae appear to winter mainly in rye, but also in winter wheat and wild grasses (Baranov, 1914) or rye, wheat, and winter barley (Rörig, 1893); so far as England is concerned little information is available, but the larvae have been found in winter wheat (Ormerod, Report for 1881, and Petherbridge, *Ann. Appl. Biol.* 1917), winter oats (Ormerod, Report for 1889), rye (Roebuck *in litt.* 1918), and in wild grasses, rye-grass, *Avena flavescens* and *Arrhenatherum avenaceum* (Edmunds, *Rep. Harper Adams Agric. Coll.* 1912). Winter wheat has also been known to be attacked in the spring, the flies hatching out at the end of June and beginning of July (Roebuck *in litt.* 1918).

NUMBER OF BROODS DURING THE YEAR.

The majority of writers are satisfied that there are three broods, though some Russians consider there may be four or even five in S. Russia. In the laboratory at Kiev four generations were reared (Dobrovbliansky, 1915) as follows:

Date when flies were placed in insectary	Appearance of damage to plants	Appearance of Imago
1. May 9	May 29	June 13–23
2. June 15	July 3	July 23
3. July 24	Aug. 11	Aug. 27
4. Aug. 28	Sept. 26	Oct. 16 (two flies only)

Kulagin (1913) considered there to be three broods with smaller intermediate ones, a fourth brood being doubtful and only if weather conditions are favourable. Schesterikov (1910) stated that the appearance of the insect is governed by weather conditions. In the Board of Agriculture Report on insects injurious to crops in 1892 (London, 1893) it was suggested that there may be a constant succession of broods dependent upon the state of food plants and the weather, and this view would appear to be supported by the statements made by Baranov, Ritzema Bos, Rörig and Kühn given at the end of the next subheading. Probably the broods more and more overlap as the season advances.

TIMES OF APPEARANCE OF FLIES.

First Brood: March (Wilhelm, 1891, Germany) to early June (Zetterstedt, Lappland and Baranov, 1912, Moscow). Widhalm (*vide* Kulagin, 1913, Russia) gives earliest appearance 28th March but more usually 14th April. The period of maximum emergence in England would appear to be from middle of April to middle of May.

Second Brood: Early in June (Wilhelm, 1891, Germany) to end of July (Dobrovliansky, 1913, Russia); according to Kulagin, 1913 (Russia), after the first summer rain in June. The period of maximum emergence in England would appear to be during July. Dobrovliansky (1913) wrote as follows concerning this brood: barley sown 21. v., first larvae observed 5. vi., pupae 15. vi., flies 6. vii.–2. viii. Petherbridge (*in litt.* 1918) states that he found swarms of the fly in an oat field on July 21st, 1912.

Third Brood: August (middle of August in many places in Russia) to October (Krassiltchik and Vitkovsky, 1913, Bessarabia; Ritzema Bos, 1891, Holland), middle of October (Stormer and Kleine, 1911), but Widhalm (*vide* Kulagin, 1913, Russia) gives the last appearance as usually end of October, sometimes as late as Nov. 14th. The period of maximum emergence in England would appear to be August and September, but in the case of wheat sown after rye-grass or Italian rye-grass the crop has been known to be attacked even when sown as late as November or early December (Petherbridge, November, 1917), apparently indicating the possibility of a migration of the larvae from the ploughed-in rye-grass to the young wheat plants (*vide* Fryer and Petherbridge, 1917). Dobrovliansky (1913) gave the following sample of the life history of this brood: Oats sown 11. vii., larvae 23. vii., pupae 6. viii., flies 12. ix.

Baranov (1912) found all stages (eggs to imago) on summer sown grain on June 27th. Ritzema Bos (1891) stated that both pupae and flies are to be found during nearly all the spring and summer, Rörig (1893) that the insect may be found in all stages at one and the same time on any occasion between spring and autumn, and Roebuck (*in litt.* 1918) that he had no difficulty in finding larvae, pupae, and imagines from the end of April until September. Rörig (1893) recorded the breeding out of flies in December and January in a warm room. Kühn (1893) collected infected plants on December 16th and kept them in a room when flies appeared in abundance at the end of January; other infected plants collected on January 26th produced flies in abundance at the end of February. Jügner (1904) gave an account of a similar experiment;

flies hatching out in January in a warm room were found to copulate and when given fresh young plants, laid eggs which hatched in a few days.

EGGS.

In the autumn and spring the eggs are laid on the leaves of the young plants (preferably on the underside), or on the stem close to the ground, Kurdjumov (1913) said at the level of the soil. Krassiltchik (1912?) in Bessarabia found no eggs on the leaves but all on the young stems. Baranov (1912, Moscow) on the other hand found them mostly upon the upper side of the leaf near the stalk, or (1914) on both sides of the leaves, sometimes on the stalk near tillering knot. In the summer the eggs may be laid on the sheaths enclosing the ears, on the panicles of oats, the young corn of oats and barley, or on wild grasses. A female may lay from 20 (Lindeman, *vide* Kulagin, 1913) to 30 (Rörig, 1893) or according to Wahl (1914) 70 eggs; and the eggs take from three to seven days to hatch (three to four days, Wilhelm, 1891; three to seven days, Rörig, 1893; four days spring, seven days autumn, Baranov, 1914). According to Dobrovliansky (1915) the maximum number of eggs laid by a female in one day is six, and while in moist air and a high temperature the eggs may hatch in three days, dry air will kill them.

LARVAE.

The young larva of the autumn and spring broods makes its way into the young stem and eats the tender central leaves and shoot, ultimately killing the shoot which in the meanwhile may produce side shoots. According to Krassiltchik and Vitkovsky (1913) the newly hatched larva may mine the leaf upon which it was laid very extensively before working its way into the stem. Several writers have noted that a larva can migrate from one shoot to another. Normally only one larva is present in each shoot, but as many as ten larvae have been found in a single plant. The summer larvae live in the summit of the stem, feeding upon the hidden ears or panicles, on the young corn in the ear or panicle, or in the stems of grasses. The spring and summer larvae may feed for 14–15 days (Baranov, 1912), three weeks (Ritzema Bos, 1891), three to four weeks (Kulagin, 1913), or five weeks (Rörig, 1893), while the majority of writers are agreed that the autumn larvae normally winter in that state and do not pupate until the early spring. Baranov (1912) gave the proportion of larvae to pupae found in the winter as 100 to 10–15. Dobrovliansky (1913) found in the Government of Kiev that on

August 26th 10 per cent. of the young plants sprouting from fallen grain were infested with larvae; and that on September 5th 20–26 per cent. of winter wheat plants were infested.

PUPAE.

The spring and autumn larvae leave the centre of the stem and pupate under the sheath of the outer leaves. Baranov (1912) says near roots, sometimes 1″–2″ in the earth. Roebuck (*in litt.* 1918) states that on oats he has invariably found the pupa of the spring brood under the sheath and between the first node and 1½ inches above; in wheat however the distribution was not so even—at first, second, or even third, node from ground and anywhere from the ligule to the node. The summer larvae pupate among the leaves surrounding the hidden ear or panicle, or in the grain itself or between the grain and the husk. The pupa stage may last 8–14 days[1] (8–10 days Taschenberg, 1879; 10–12 days Schesterikov, 1910, and Baranov, 1912; average 14 days Lindeman, *vide* Kulagin, 1913), the length of time being governed by the amount of moisture, the dryer the conditions the longer the period (Dobrovliansky, 1915). Experiments made by Krassiltchik and Vitkovsky (1913) proved that flies were capable of getting through 7″–9″ of rammed wet earth upon emergence from pupae buried at that depth.

IMAGO.

According to Kulagin (1913) Kurdjumov in Russia found that the male lives a very short time, often dying the same day; a female lived for two weeks in captivity, and he estimated its life when free at about a month, but Kurdjumov (1913) himself stated that he found the length of the life of the adult to be two to three months (under exceptionally favourable circumstances five months), and Dobrovliansky (1915) gave the length of the life of the male in captivity as about a month, while four females lived 74, 55, 45 and 63 days respectively, and the period during which they oviposited was 24–36 days. Most writers refer to the short hopping flight of the insect.

The appearance in immense numbers of the flies from grains threshed at harvest has been several times recorded.

"From oats threshed in the field and stored in bulk in loft" (England, Westwood, 1881).

[1] Compare also Dobrovliansky's sample life histories of second and third broods given under the subheading "Times of appearance of Flies."

"Oats drilled April 1st on late folded land, threshed in August and found very light in weight (32 lbs. per bushel). Innumerable flies swarmed a few days later in granary where corn was stored" (England, Theobald, 1906).

"Large numbers of flies bred from store of threshed oats at Poltava" (Russia, Vassiliev, 1908).

"In swarms in an outbuilding this autumn (1881), in the lofts of which newly threshed barley had been stored" (Meade *in litt.* 1881, Ormerod, Report for 1881).

"Found in great numbers in a loft in Dorsetshire where barley had been stored" (Fitch, *Proc. Ent. Soc. Lond.* 1881).

"A number of these little flies were sent to me some years ago by the Rev. O. Pickard-Cambridge, which he had found in a granary in Dorsetshire in which (I think he said) barley had been stored" (Meade, *Ent. M. Mag.* 1899, p. 103). It is possible that these three last references refer to one and the same case.

SYNONYMS AND VARIETIES.

The original description of *Oscinis frit* was made from specimens bred from the ears of barley. *Musca hordei* Bjerk. was bred from rye and subsequently considered by Bjerkander himself to be a synonym of *frit*. *Musca avenae* Bjerk. was bred from the stems and panicles of oats. *Oscinis vastator* Curtis from young wheat plants sent to Curtis towards the end of June. *Oscinis granarius* Curtis was bred from a grain of wheat. Of these *granarius* was distinguished by Curtis by having the tibiae black with only the tip of the intermediate tibiae (front pair missing in type specimen) yellowish, *O. vastator* by having the base as well as the tip of the four anterior tibiae ferrugineous. Specimens bred from oats threshed early and stored in a loft were described by Westwood as having the legs uniformly black, and these he considered to be identical with *avenae* Bjerk. and *atricilla* Zett. *Oscinis pusilla* Mg. has been recorded as living in cereal crops, but the *O. pusilla* of Wilhelm which he called the "Oat-fly" and which attacked the oats in the panicles in its summer generation, and was described by him as having the tibiae of only the front legs a little paler, the others dark as the femora, is certainly not the same species as Meigen's. True *O. pusilla* Mg. has the four anterior tibiae entirely yellowish

Very little information is available as to whether different varieties are responsible for the attack on different plants or different parts of the same plant; the variety *pusilla*, however, has been noted by different

writers on the Continent as attacking only rye in the winter generation and only the panicles of oats in the summer generation, whereas these generations of *frit* are recorded as not being so particular as to the object attacked.

PARASITES.

Sigalphus caudatus (Curtis, 1860); *Pteromalus puparum*, *P. micans*, and *Sigalphus caudatus* (Rörig, 1893); *Rhoptomeris wildhami* Kour. and *Trichomanus cristatus* Forst. (Baranov, 1912); *Polyscytus oscinidis* Kurd. sp. n. (Mokrzecki, 1913); *Mersius intermedius* and *Semiotellus nigripes* Lindm. (Wilhelm, 1891); *Miris dolobratus* and *Pteromalus micans* (Schesterikov, 1910); Coccinellidae destroy the larvae (Wilhelm, 1891, Rörig, 1893 and Schesterikov, 1910), and an unclassified entomophagous fungus kills considerable numbers (Schesterikov, 1910).

Dobrovliansky (1913) found that in barley sown on May 21st in the Government of Kiev, 21 per cent. of the pupae of *frit* were parasitised, and on oats sown July 11th 16 per cent. of the pupae were parasitised.

RESISTANCE TO ATTACK OF DIFFERENT VARIETIES OF CORN.

Very indefinite conclusions have been arrived at on this point. Kulagin (1913, Russia) recorded "Triumph" oats and naked barleys as suffering most. Rörig (1893, Germany) said that experiments apparently showed that "Triumph" and other "bearded oats" (*Fahnenhafer*) were less attacked. Aurivillius (1892, Sweden) came to the conclusion that "six-rowed" barleys were much more liable to attack than "two-rowed" barleys. McDougall (1912) found that in Scotland "Hamilton" and "Potato" oats were least damaged, followed by "Sandy," "Wide-Awake" and "Abundance," while "Tartar King," "Beseler" and "Banner" were very badly attacked; this would appear to support the view that those oats that tiller freely are better able to stand against attacks of frit-fly than those that do not.

In the Report on the breaking up of grass land in 1916–17, published by the Board of Agriculture in 1917 as *Miscellaneous Publications*, No. 19, a case is recorded from Yorkshire where two varieties, "Bountiful" and "Beseler's Prolific," were sown in April on a ten acre field which had been broken up in February. "Bountiful" provided an excellent crop of 7 qrs. per acre, but "Beseler's Prolific" suffered greatly from frit-fly and was a much lighter crop.

Ritzema Bos (1894) recorded some observations on a number of varieties in Holland in which he found that "Longfellow," "White Canadian," "Black Canadian" and "Early Blossom" exhibited considerable powers of resistance.

CONDITIONS FAVOURABLE TO AN ATTACK.

It is the universal opinion that *late sown* spring crops are most affected, and the evidence of many cases submitted to the Board of Agriculture strongly supports this opinion. The date of the commencement of the dangerous period is probably dependent upon weather conditions and would therefore be best indicated by association with some natural phenomena also governed by the same conditions. Past experience has tended to show that spring corn sown before the end of March is usually not attacked; occasionally it may be safe to sow up to the middle of April on a good tilth, but after that date an attack is very probable in *frit*-infested districts. Professor M'Cracken of the Royal Agricultural College, Cirencester, writing to Miss Ormerod in 1889 (Ormerod, Report for 1889), stated that "Black Tartarian Oats sown on March 29th enjoyed almost complete immunity from attack; in another field sown on April 29th, over 70 % of the first stems were destroyed"; while in the *Annual Report of the Intelligence Division*, Part II, published by the Board of Agriculture in 1911, it was stated that crops sown early in March have been known to escape when others sown late in March were infested. In a Report on the breaking up of Grass Land in England and Wales in the Harvest Year 1916 17, published by the Board of Agriculture and Fisheries as *Miscellaneous Publications*, No. 19, in 1917, it is stated that "Frit flies are most troublesome in the case of crops sown in mid-season. Oats sown before March 15th and after April 15th may escape when crops sown between these dates may be destroyed." No authority for the statement that oats sown after April 15th may escape can be traced, while this statement is certainly in opposition to the expressed views of all economic entomologists in this country. Reports of bad frit-fly attacks on crops "after grass" were frequently received in 1917, and it is worthy of note that in Canada grasslands ploughed late in autumn or in spring are stated to be attacked the worst (Criddle, 1916).

Enquiries instituted by the Board of Agriculture in 1909–10 and published in Part II of the *Annual Report of the Intelligence Division* in 1911 appeared to show that late sown oats following roots fed by sheep, when the fields were only once ploughed and not much cultivated, were most attacked. Ormerod (Report for 1881) noted attacks on wheat on land fallowed the previous year, no attacks where land ploughed first time in autumn. Fitch (1881) stated that wheat after a whole summer's fallow was almost invariably attacked. It must be remembered that in some of these cases of attacks on wheat the real cause of the damage may

have been *Hylemyia coarctata*, the damage by this insect and by *Oscinia frit* often being confused (*vide* Wahl, 1914 and Dafert and Kornauth, 1914). It has been noted that on a field of wheat after Italian rye-grass and clover, where it was ploughed in July, bastard fallowed, and drilled on October 3rd, there was no *frit* attack; while another part of the same field where the grass and clover crop was fed off by sheep, ploughed on October 1st and drilled on October 3rd, 10 per cent. of the wheat plants were attacked (Petherbridge, November, 1917). On the Continent, in addition to late sown spring crops on newly broken land, spring corn planted next to winter rye is almost always attacked, the attack spreading from the rye in parallel lines or concentric circles (Cohn, 1869).

POSSIBILITY OF INFECTION FROM INFESTED SEEDS.

Those larvae attacking the grain of oats in the panicles, often pupate within the husk of the oat and remain in the corn after it is threshed; the flies normally emerge during August and September and several records of the occurrence of swarms on oats threshed early in August have been noted (*vide* under "Imago"). In order to account for infection from the seed it would appear necessary for there to be either (1) deferred emergence on the part of some of the flies from pupae in the grain, or (2) oviposition on the corn by the females of the emerging flies, with the larvae hatching out after the corn is planted. Neither of these suppositions appears very probable, but attention has been called to this possible source of infection by Miss Ormerod in 1889, by the author of an article in the *Journal of the Board of Agriculture* for September, 1901, and by Kulagin (1913) in Russia; while quite recently (1917) in England observations have been made in districts where *frit-fly* is very prevalent that when seed from districts where oats do not suffer to the same extent from the fly has been used, the crops in some cases have not been seriously attacked, and that where seed has been dressed with corvusine, seedolin, or sulphate of copper, the crops have been fairly free from attack (Bland, July, 1917). Moreover, in an experiment in which seed from a badly attacked field was sown under a fine mesh muslin frame which seemed to be impervious to the flies, an examination of half the plants at the end of June brought to light two *frit* larvae (Roebuck, Shropshire, 1917 *in litt.*).

REMEDIES.

Spring sowings should be as early as possible, and the early growth stimulated in order that the young plants may be as forward as possible at the time of appearance of the first brood of flies, for then the small

weak side shoots only will be attacked. The best time for this sowing probably varies according to the season, but crops sown in March (the earlier the better) usually enjoy immunity from attack. It must be remembered, however, that early sowing on a bad tilth or too early sowing, with damage from frost, may result in a more backward plant than somewhat later sowing. Sulphate of ammonia and sodium nitrate appear to be two of the best top dressings for young oats, and in regard to these it has been specially noted in the Oxford district (Bland, July, 1917) that sodium nitrate, applied as soon as the oats are through, gave better results in a dry season than sulphate of ammonia applied when oats were drilled.

Vassiliev (1914) has recorded some of the results of experiments made in 1911 in the Government of Petrograd on the effect of manure on the yield of *frit* infested oats in a table as follows:

Manures	Percentage of plants attacked		Percentage of plants not producing normal grain		Percentage of plants killed		Yield per dessiatine (=2·7 acres)	
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2
Unmanured	45	41	48	49	22	20	115	68
Superphosphate	33	35	32	29	11	10	125	77
Superphosphate and Potash	40	52	26	46	10	24	142	66
Sodium nitrate and superphosphate	32	39	17	15	5	6	158	96
Sodium nitrate, superphosphate and potash	40	43	11	24	4	10	156	112

The important facts may be shortly summarised as follows:

Percentage of infected plants on all plots 40
Percentage of plants completely killed on unmanured plots 21
Percentage of plants killed on plots manured with superphosphate at rate of about 267 lbs. per acre and sodium nitrate 80 lbs. per acre ... ... $5\frac{1}{2}$
Percentage of plants on unmanured plots not producing normal grain ... ... $48\frac{1}{2}$
On plots manured with superphosphate and sodium nitrate as above the percentage of plants not producing normal grain reduced to 16
The addition of potash at rate of 80 lbs. per acre to above manures, in one case reduced the percentage of plants not producing normal grain to 11
Increase in yield 37 % in one case, 65 % in another.

He found that oats damaged by *frit* when manured with sodium nitrate tillered well, producing new shoots which ripened at the normal time, and came to the conclusion that damage caused by anything up to 40 per cent. of *frit* infestation could be reduced to practically nil if proper manures were used under suitable conditions.

Spring sowing should be avoided, when possible, on or near fields which were attacked in the previous year. With regard to the seed, early varieties, and such as are best suited to the soil and locality, should be chosen.

In 1917 in the *frit*-infested county of Oxfordshire it was found that the best time to roll the fields sown with spring oats was immediately after the seed had been drilled, or at least before the young plants were through the ground; oats rolled later, probably owing to the check in their growth, were more severely attacked (Bland, July, 1917).

Rörig (1893) recommended that a forage crop should not be sown with oats or barley on a field that had been affected, but this advice was directed to continental farmers. It would appear that grass layers or newly cultivated grass or waste-land should be ploughed early in the summer and bastard fallowed before planting with winter wheat (Petherbridge, November, 1917). It should be remembered that on a field which has been attacked and the crop harvested, the grasses and young plants growing from the shelled-out corn are probably badly infested; these should therefore be ploughed up early.

Kulagin (1913) mentioned an experiment recorded by Lindeman (Russia) in which a field was sown with rye on August 10th next to a badly infested crop of oats; in the ordinary course the complete destruction of the rye would have been certain, but on August 13th (before the rye had sprouted) the oat field was ploughed up, with a result far exceeding expectations, there being no subsequent damage to the rye. Fields should be kept clean of grass, and the destruction of grass borders round fields, and grass edgings to field roads has been recommended.

OBSERVATIONS.

This summary must not be accepted as complete, as many observations may have been overlooked, and the publications in which some are recorded have been inaccessible; also it naturally contains many conflicting and probably often inaccurate statements, and impracticable advice, but it should prove of some value to those who are working, or about to work, at the frit-fly problem.

There are still very many points in the bionomics of the frit-fly requiring elucidation, and a very large amount of experimental work to be done, before the efficient control of this pest can be assured; moreover, research and experimental work undertaken in (say) Russia cannot be relied upon as giving correct data for England. The climatic conditions and the agricultural methods differ so much in different countries, that

it is quite possible the life history of the fly will be found to be more or less modified; for the same reasons, experimental work in controlling the pest may be found successful in one country, but fail in another.

It is remarkable that no definite experiments, beyond those of Krassiltchik and Vitkovsky mentioned under "Pupae," appear to have been made as to how far the fly can be controlled by being buried under the ground in its earlier stages, especially as to whether the larva can complete its feeding and pupate after the affected plant has been ploughed in.

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ON THE TRANSPORT OF HERRING SPAWN TO THE SOUTHERN HEMISPHERE.

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Two unsuccessful attempts have been made to transport the ova of the herring to New Zealand. The first was, I believe, made in the eighties.

As a preliminary to a second attempt certain experiments were made at this laboratory, and in 1913 Mr Anderton, of the Marine Fish Hatchery, Portobello, Dunedin, conveyed some spawn along with small turbot, and adult crabs and lobsters, which were secured for him through the very efficient assistance of the staff of the Plymouth Biological Laboratory. Mr Anderton's labours resulted in 191 turbot, 43 crabs, and 41 lobsters being landed alive in New Zealand—an achievement reflecting the greatest credit upon him. The late Mr H. C. Dannevig had previously transported a number of plaice alive to Australia.

The herring ova survived till the steamer reached Cape Town. The water supply was on more than one occasion dirty with rust, and other sediment. The ova became coated with this matter, and although the plates were cleaned more than once, the eggs all died off.

The method adopted for the conveyance of the spawn, which is adhesive, was to cause the eggs to adhere to glass plates. The plates were put into a frame which slowly revolved, submerged in water. A current of water flowed through a series of boxes in each of which a frame carrying four glass plates rotated.

During incubation the current flowing over the eggs must be strong. It is not very easy to cool down a large quantity of water continuously, and the arrangement of rotating the plates was adopted in order to change the water in contact with the eggs. Mr Anderton reported that this apparatus worked well. New water was being steadily added, and none of the water was used a second time. This was possible because Mr Anderton had his tanks in a cold storage compartment, and brine-cooled coils reduced the temperature of the water which was supplied from an overhead tank.

Where a cold storage room is not available, or where the expense involved in its use is considered greater than should be incurred in a preliminary experiment, the cooling may have to be done with ice, and to reduce the quantity of water to be cooled to its smallest limit would be an advantage. Such an end might be secured if the cooled water were recirculated.

For the voyage to New Zealand it was necessary to prolong the period of incubation to 50 days. To retard hatching for that time, it was necessary to keep the ova at a temperature of about 35° F.

The Provincial Cape Government has had under contemplation the possibility of introducing the herring into South African waters. How far it may be possible to acclimatise the herring there is not to be solved *a priori*. In such matters an ounce of practice is better than a bushel of theory. The only answer to be trusted is that furnished by experiment. And if the experiment can be carried out without an undue expenditure it is well worth doing.

In order that the ova reach Cape Town unhatched they require to be exposed to water of a temperature of from 39° to 46° F. This is the range of temperature ordinarily exhibited by the water of this laboratory in March. During the voyage the sea-water may have to be cooled down from a temperature of 86° F.

So far no method has been devised of incubating the ova except in a current of water. I have been able to keep the eggs of the herring alive in stagnant sea-water, a third of which was renewed daily. Some survived for 20 days at a low temperature; the majority was dead by the end of that period; all died without hatching. Similarly some of the ova which were kept in dead moss wet with sea-water, remained alive for 19 days, but they also died, without hatching. It is quite possible that these methods might be successfully developed. That would simplify the problem very much.

It is possible to keep certain marine animals alive in sea-water that is unchanged during a considerable period, all that is necessary being to drive air into the water. The excretory products do not then apparently seriously pollute the water. Where there are dead eggs present, the air current is not sufficient to keep the water in an innocuous condition. The water must be changed; to what extent is a matter for experiment. In the case of artificially spawned eggs it is probably impossible to avoid having some eggs die during incubation, and the dead eggs cannot be readily removed from among the living herring spawn.

Among the eggs of the herring which were incubated at this labora-

tory, the death-rate was often large; in some cases all the eggs of a batch succumbed without hatching. There are various factors which one can suppose will or may injuriously affect the ova, and it is necessary to eliminate them as far as possible.

So far as the water was concerned the only precaution which was taken was against mud, etc. in suspension: the water was filtered through sand. Since ova develop in the water, it was considered that a suitable environment for the eggs depended simply on the quantity of water supplied. When however it is desirable to reduce the quantity of water employed, its quality, in respect to the quantities of dissolved gases and of matters in solution, as well as the bacterial content, demands attention. Mr Anderton considered that the water of the tropics when cooled down was short of oxygen. Therefore a means of adding to the air content would be necessary. The quality of the air which is bubbled through is important[1]. There is further in this connection a certain risk that may follow from the supersaturation of the water with gases. Some fishes have suffered through such a condition. Gas-bells may form in the tissue and cause death. I have observed a gas-bell inside the dead egg of plaice which had been in water into which air had been pumped in great quantity. But the bells did not occur in all the dead eggs: they appeared to be an exception.

There is, in certain places, an important difference in quality between the shore-water and off-shore water. Cunningham[2] reported that the water from the shore at Plymouth, although constantly supplied in a pure condition to the eggs in the circulation apparatus, was rapidly fatal; while in the water from the open sea, although perfectly still and unchanged, the ova lived.

In the herring eggs which were incubated in water cooled below the temperature prevailing, viz. 39°–46° F., crystals were often found[3]. The crystals were rectangular, sometimes ending in an oblique tapering point. They may be fine needle-like, or fairly thick bars. They have been observed on the inside of the zona, between the layers of the zona, attached to the yolk or embryo; in two instances they were noticed inside the gut of the living embryo.

The cooled water was restricted in amount, and it was cooled in galvanized iron pipes. I consider that these crystals resulted from

[1] Cf. Shelford and Allee, *Journ. Exper. Zoology*, Philadelphia, XIV, 1913.

[2] *Journ. Mar. Biol. Assoc.* 1889–90.

[3] Cf. Williamson, H. C., "The retardation of the Development of the Ova of the Herring," *Fisheries Scotland Sci. Investig.* 1910, II (1911).

deficient aeration, but I have also thought that they were in some way due to the galvanized metal. They did not however appear in all the eggs of a plate: they occurred in both living and dead eggs. They were observed in certain of the eggs of a plate which was rotated. In one instance the crystals appeared in the egg within 36 hours after fertilization.

The layer of eggs was, towards the end of the period of incubation, often attacked by a fungus. The mould grew in water of 37° to 43° F. Whether it was the cause of the death of the eggs, or whether it grew there in consequence of the death of the ova I was unable to decide. It probably was instrumental in killing some of the eggs. Diatoms have also grown on ova exposed to strong light; it is better therefore that the eggs be screened.

Mr Anderton used tanks of wood, coated with asphaltum. I now think that earthenware vessels would be preferable for the spawn.

How far sterilized water would be an advantage is uncertain. Stone[1] preferred for his successful transport of fishes and lobsters across the American continent, sea-water which had stood for two or three weeks covered and perfectly still, to sea-water that had been boiled. "At the end of the three weeks the miscroscopic creatures will be found at the bottom of the tanks, in the form of a deposit of slime. The water above will be perfectly sweet and clear, and it will remain so indefinitely."

I think however that there is reason to doubt that the environment is the sole cause of the death of the ova. It seems to me that the eggs differ in vitality. It is noticeable that about 48 hours after spawning, the eggs on the plates very often look well: with very few exceptions they are fertilized. One might infer then that all that was necessary, was to provide a suitable environment, in order that all may eventually hatch. The eggs however gradually die off: a certain proportion survives and hatches. Any difference of environment of the ovum due to its particular position on the plate, or the fact that two or three other eggs crowd it closely, cannot surely, except in a few cases, account for its death. The eggs of fishes are known to exhibit very great vitality. Both pelagic and demersal eggs are recorded as having been frozen and still they hatched out, after thawing.

In the case of artificially spawned eggs one may argue that the ova, on being pressed out of the fish, may receive slight mechanical injury, which does not inhibit fertilization, but only permits development up to a certain point.

[1] Stone. *Report U.S. Fish Commission*, 1879 (1882).

There is the question of how much milt the ova require. The most common method of spawning salmon eggs is to bathe them in the milt, water being added after a short time. Jousset de Bellesme states that "the robustness of an organism would depend in great measure on the number of fecundating elements which entered the egg." There would however appear to be a danger from water which was excessively laden with milt. I have observed a white deposit of milt in the interstices of the eggs, and that would no doubt prove to be a source of danger through its decay.

The spawn on glass plates is easily handled; but when the eggs have been attached to gravel satisfactory results have also been obtained. Such spawn is conveniently incubated in a box having a sieve bottom. The water finds issue through the bottom after passing among the gravel. If the box is now and then lifted and then pressed down into the water an effective change of water is secured.

There is a reasonable expectation that naturally spawned herring ova could be dredged during February, or March, at Ballantrae Bank, Firth of Clyde, and it seems likely that such spawn would stand transport better than the artificially spawned ova. The spawn secured in this way would probably not be newly deposited, still development might be thereafter retarded sufficiently for the object in view.

Some herring ova, after incubation at from 37° to 40° F. for 19 days, had embryos in an advanced stage. The eggs were then treated with water of 33·8° to 37° F. The first larva appeared on the 30th day, and hatching proceeded for the next 12 days. Eggs left at the original temperature hatched in from 23 to 36 days. In another case the spawn began to hatch on the 20th day; the temperature of the water had been 38° to 44·5° F. Thereafter the temperature was lowered, and the larvae hatched out daily till the 41st day. All the eggs in a batch do not hatch out simultaneously; there have occurred, during the experiments, intervals of 5 to 21 days between the appearance of the first larva and the last to hatch.

There is another alternative method of obtaining the spawn; that is to arrange, if possible, that the herrings spawn in confinement. Ewart[1] described the spawning of herrings in Rothesay Aquarium.

[1] Ewart, C., "Natural History of the Herring." Plates. *2nd Ann. Report Fisheries Board for Scotland*, 1883, p. 61.

THE LARVAL AND PUPAL STAGES OF *SCATOPSE NOTATA*, L.

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(With Plate X and 7 Text-figures.)

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1. INTRODUCTION AND HISTORICAL REMARKS.

The material used in this investigation was obtained at Holmes Chapel, Cheshire, at the end of October 1917; a small number of fully grown larvae were found in the decaying remains of a wasp's nest, the latter apparently having been destroyed some time previously. The remains consisted of parts of the nest and of the wasps, with organic matter of other kinds, fallen leaves, etc.

The larvae obtained were kept in the laboratory, and pupated soon afterwards, remaining in the pupal state about fourteen days, but the exact period was not noticed. Bouché(1) gives this period as eight to fourteen days.

I have to thank Mr C. G. Lamb, M.A. of Cambridge, for his kindness in confirming my identification of the adult, and Dr A. D. Imms, who suggested this investigation to me in the first instance, and who has assisted me in many ways throughout its course.

De Geer (1776) has given a short description of the life history of this species under the name of *Tipula latrinarum*. Bouché (1834) also has given an account of it as *Scathopse noir* Geoffr., which is probably

the present species. Perris (1847) has also given an account of this species under the name of *Scathopse punctata* Meig. None of these observers however give detailed descriptions or figures, and their accounts are not entirely free from inaccuracies. Sharp(8) has drawn attention to the fact that while Bouché considered that the larva possesses nine pairs of spiracles, Dufour and Perris considered it to be amphipneustic.

2. THE LARVA.

The larva when fully grown is about 7 mm. long and 1 mm. broad at its widest part, and its thickness is rather less than its width. It is clearly divided into two regions, (i) the *Head*, and (ii) the *Body*.

The *Head* is about ·48 mm. long, and ·43 mm. in width, and is invested by a brown chitinous capsule which is considerably darker and stronger than the covering of the body. The anterior part of the head is rather darker than the posterior part and bears a few short setae, some of which occur in groups. There is no indication of eyes.

The antennae are small but conspicuous, and consist of a basal portion which bears several processes at its apex, one of which may be a much reduced second joint (Text-fig. 5).

The labrum is somewhat triangular in vertical section, the apex projecting between the mandibles. The ventral side of the labrum bears many setae of several types and also chitinous processes, possibly of a sensory nature (Text-fig. 3).

The mandibles (Text-fig. 1) are strong and bear six teeth. Of these teeth five are in a row and are directed in such a manner that in the natural position they project ventrally and slightly inwards, while the sixth tooth is separate and projects dorsally, towards the other five. The maxillae (Text-fig. 2) consist of a basal portion which bears a stout undifferentiated lobe, upon which are a number of setae and chitinous processes. A single jointed maxillary palp is present and bears on its ventral surface an annular depression within which are a number of short projections. On the apex of the palp are a few processes and setae. The labium is composed of a flat dorsal plate, which is supported below by two small sclerites, of which one is anterior to the other. These two parts project beneath the head, and bear a large number of setae (Text-fig. 4).

The *Body* is nearly cylindrical, but it is rather flattened dorso-ventrally, while its diameter decreases from about the middle towards both ends (Plate X, fig. 1). It consists of twelve segments and is curved longitudinally, the ventral surface being almost straight and the dorsal

surface convex. It is a dirty white in colour, but this colour is obscured during life by particles of soil, etc. which adhere to it and give it a much darker appearance. During life the form of the larvae, in particular of the posterior end, was very much obscured by adherent particles.

The larva bears nine pairs of spiracles, which are situated a pair on each segment, on the first and the fourth to eleventh segments inclusive. The spiracles are brown in colour and are situated laterally. They are placed rather nearer the anterior than the posterior border of the segments except for the pair on the eleventh segment. These latter spiracles are considerably larger, and are situated in a more dorsal position on the posterior margin of the segment. All the spiracles project considerably from the body, the amount of the projection being more than twice the diameter of the spiracle. The last pair, however, projects to a much greater extent than the previous pairs, each spiracle being about as long as the twelfth segment.

The spiracles on the eleventh segment bear near their apices a number of fine setae projecting downwards towards the body. The other spiracles are rather spatulate in shape, those on the first segment being slightly larger than the others.

The structure of the posterior spiracles is very similar to that of the spiracles of *Bibio* larvae, in that the opening is within a funnel which is supported internally by a system of trabeculae (Text-fig. 7).

The segments of the body bear a large number of setae, which vary in length on the different regions. The first ten segments each bears on the dorsal surface a transverse row of numerous setae, placed near the posterior border. In front of these bands of setae are five short broad longitudinal rows, of which the central one is median in position with two rows on either side of it. On segments four to ten the outermost of the longitudinal rows of setae are inclined inwards anteriorly, and become confluent or nearly confluent with the adjacent row of setae.

The eleventh segment bears dorsally a single median transverse row of setae, this row being continued backwards, at the sides, to the posterior margin of the segment.

The twelfth segment, which is much smaller than any of the preceding segments, bears a pair of large reddish-brown processes at its posterior end. These processes are about equal in length to the segment and bear a number of long setae, which are spread out in a fan-like manner. (Plate X, fig. 4.)

The anterior part of the ventral surface of the first segment projects slightly, and is covered with small setae. Ventrally, the fourth to tenth

segments bear two transverse rows of setae, with a number of small groups of setae. The first three segments are without the two transverse rows, but bear instead a pair of groups of setae. These, especially on the second and third segments, are rather horse-shoe shaped, with the opening anteriorly.

The eleventh segment bears, on its ventral surface, a transverse row of setae, near its posterior margin. Placed in front of these setae is a second but incomplete transverse row.

The twelfth segment is provided ventrally with a number of large setae surrounding the anus, with a smaller row on each side.

Between all the segments, both dorsally and ventrally, are a number of short spines. On the first three segments they are arranged in groups of from three to five in a short row (Plate X, fig. 8), while on the remaining segments they are separate and not grouped together (Plate X, fig. 7).

On the first two segments the dorsal transverse row of setae is composed, on all the larvae I have been able to examine, of short blunt processes, which in size and colour resemble the basal part of the largest and longest of the other setae. In some cases the tops of these processes were flat, as if the upper part had been broken off, but some of them were rather conical in shape.

3. THE PUPA.

The pupa (Plate X, figs. 2 and 3) is formed within the larval skin, which is persistent and remains entire except for a longitudinal slit exposing the back of the thorax of the pupa. It foreshadows, therefore, the puparium of the higher Diptera.

The pupa does not completely fill the larval skin, an empty space being left within the skin at both ends. The abdominal spiracles of the pupa project through the larval skin laterally, and are closer together than those of the larva. The thoracic spiracles are exposed by the splitting of the anterior dorsal part of the larval skin. The larval skin thus affords some slight protection to the pupa: this protection must, however, be very slight as the skin is easily torn.

The pupa, when completely removed from the larval skin, is of a uniform reddish-brown colour and is about 4 mm. long, 1·2 mm. broad across the thorax and 1·3 mm. broad across the widest part of the abdomen, which is slightly flattened.

There are six pairs of abdominal spiracles. These project laterally to the extent of about ·11 mm. and are situated on the anterior part of

the second to seventh segments. Each spiracle bears a number of minute openings at its apex.

There is also a pair of prothoracic spiracles, which are dorsal in position. Each arises from an enlarged base and is a considerably branched structure, with a length of about ·24 mm. At the apex of each of the branches are a number of minute openings.

On the ventral surface of the thorax the sheaths of the legs, wings and antennae are visible, but they are much more closely attached to the body than is the case with the pupa of *Bibio*(6). The head is adpressed to the prothorax, and the antennal sheaths curve outwards and backwards, extending to the base of the wing sheath of the same side.

The leg sheaths lie side by side, those of the first and second pairs meeting in the middle and, along with the wing sheaths, cover the underside of the meso- and metathorax. The sheaths of the third pair of legs are almost entirely covered by the wing sheaths, only their extreme apices being exposed. The leg and wing sheaths extend nearly to the posterior margin of the first abdominal segment (Plate X, fig. 3).

The parts of the sheaths of the appendages which are directed outwards, are composed of a tough cuticle similar to that covering the greater part of the body. Those portions of the sheaths which are closely adpressed to the body, consist of a delicate colourless membrane. A similar delicate membrane invests those portions of the body which lie beneath the sheaths of the appendages.

Dorsally the thorax bears a slight longitudinal ridge extending from the hind margin of the mesothorax to the anterior extremity of the pupa. This ridge is exposed by the slitting of the larval skin, and along this ridge the pupal cuticle divides for the emergence of the imago.

On all the abdominal segments, both dorsally and ventrally, are a number of small oval depressions, which are slightly paler in colour than the other parts. The pupa is covered with minute blunt processes, which are usually circular in shape. These structures, however, are absent from the oval depressions just mentioned, from the intersegmental parts of the abdomen and from the spiracles and their bases.

4. GENERAL REMARKS ON THE MORPHOLOGY AND AFFINITIES OF THE LARVA.

It has been already mentioned that both Dufour and Perris considered the *Scatopse* larvae, which they described, to be amphipneustic. Bouché, on the other hand, stated that the larva carried nine pairs of spiracles, which is the correct number. Dufour mentioned that the

larva bore a pair of brown projections on each segment of the abdomen which, however, he did not consider to be spiracles, although they are almost certainly the structures which have now been found to be undoubted spiracles.

Dufour also considered that the larva had no mandibles, although they are distinctly present. As they are somewhat difficult to separate from the maxillae, this may account for Dufour's failure to distinguish between the mandibles and the maxillae.

In previous accounts of larvae of this genus, it is stated that the body is composed of eleven segments. The eleventh segment is described as being large, and divided dorsally into two distinct regions, the anterior region bearing the pair of large spiracles, and the posterior region bearing the posterior processes.

After a careful examination of this apparent eleventh segment, it appears to me to be distinctly composed of two segments, both regions being actually complete segments. The division between these segments is not very marked dorsally, but there is a slight transverse depression just posterior to the spiracles, which bears a few small setae similar to those borne between the other segments. Ventrally the division between the eleventh and twelfth segments is more clearly marked.

The posterior processes appear to have a somewhat similar structure to that of the spiracles, and they may be a modified pair of spiracles. It seems more probable, however, that they have been formed by the modification of some structure similar to the protrusible conical structures which are found in the larva of *Bibio Johannis*(6). In another species of *Bibio* larva, of which it is hoped to give an account at a later date, these structures are more strongly developed than in *B. Johannis*. They distinctly suggest that some structures, more or less similar to them, may have developed into the processes of the *Scatopse* larva.

The larva of *Scatopse* agrees with that of *Bibio* in possessing twelve trunk segments, in the projecting spiracles, and the fact that the hindmost pair is greatly enlarged and the anterior pair slightly enlarged. This larva further agrees with that of *Bibio* in the absence of eyes.

It differs, however, from that of *Bibio* in the fact that the hindmost pair of spiracles is carried on the eleventh and not the twelfth segment and are much drawn out to form conspicuous elongate processes. Other important differences are seen in the absence of the characteristic cuticular processes so well displayed in *Bibio*, in the single jointed maxillary palpi, in the pair of fan-like caudal processes to the twelfth segment, and in the pointed and more triangular head.

The pupa of *Scatopse* differs from that of *Bibio* in being broader and less tapering towards the anal extremity, in the presence of branched prothoracic spiracles, in the prominently projecting abdominal spiracles, and the total absence of the cephalic and caudal processes. A further difference is afforded by persistence of the larval cuticle to form a covering for the pupa.

Until the larvae and pupae of other genera of Bibionidae have been fully studied it is scarcely possible, in our present state of knowledge, to judge whether these differences are of a sufficiently fundamental nature to lend support to the view of certain systematists who elevate the Scatopsinae to family rank. So far as my observations go, however, they do afford some justification for that conclusion.

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DESCRIPTION OF PLATE.

Fig. 1. Fully grown larva of *Scatopse notata*. *sp*, spiracle of first segment; *sp*, spiracle of seventh segment; *sp*, spiracle of eleventh segment. ×20.

Fig. 2. Pupa of *Scatopse notata*, dorsal aspect. *ps*, prothoracic spiracle; *as*, first abdominal spiracle. ×20.

Fig. 3. Pupa of *Scatopse notata*, ventral aspect. *an*, right antenna case; *l*, leg cases; *w*, right wing case. ×20.

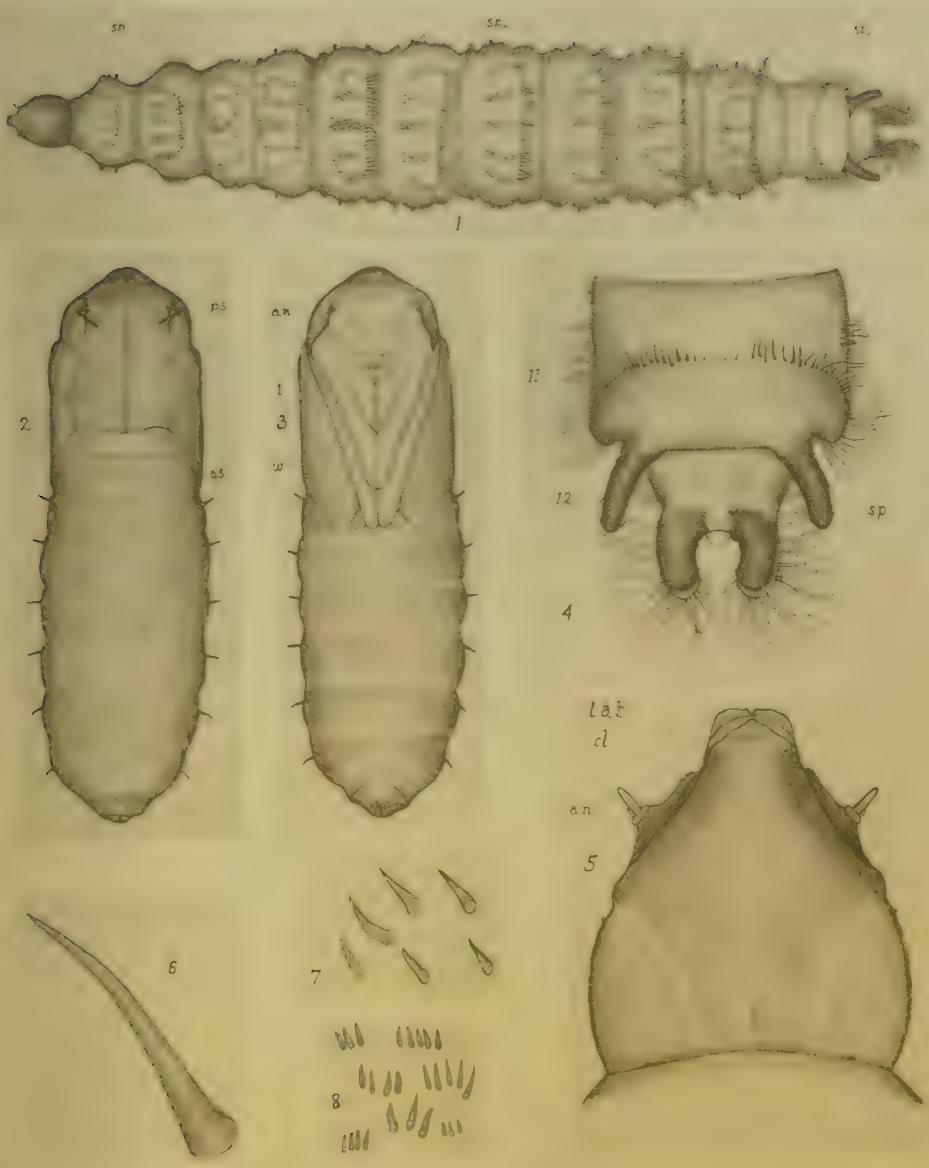
Fig. 4. Posterior end of larva, dorsal aspect. 11, eleventh segment; 12, twelfth segment; *sp*, spiracle of eleventh segment. ×52.

Fig. 5. Head of larva, from above. *an*, left antenna; *lab*, labrum; *cl*, clypeus. ×115.

Fig. 6. Typical seta. ×625.

Fig. 7. Small setae of the type found on segments one and two. ×625.

Fig. 8. Small setae of the type found on other segments. ×625.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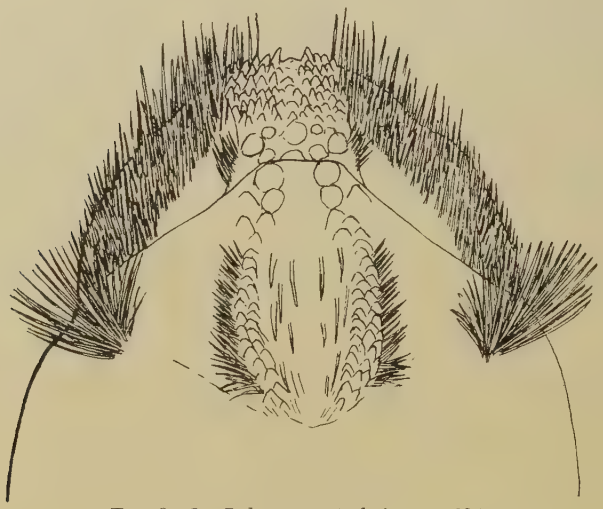
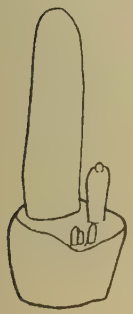
Text-fig. 1. Right mandible, from the right side. ×625.

Text-fig. 2. Right maxilla from ventral side. *p*, maxillary palp. ×625.



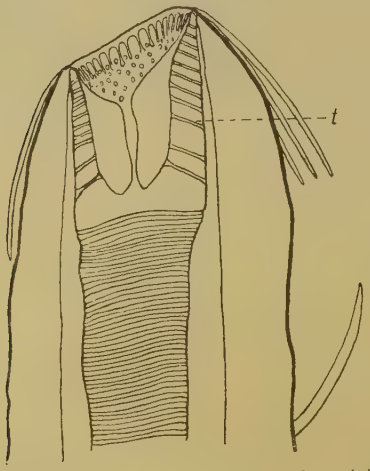
Text-fig. 3. Labrum, ventral view. ×625.

Text-fig. 4. Labium, ventral view. ×625.



Text-fig. 5. Right antenna. ×750.

Text-fig. 6. Left prothoracic spiracle of pupa. ×250.



Text-fig. 7. Left posterior spiracle of larva, optical section. *t*, trabeculae. ×600.

PHYSIOLOGICAL PRE-DETERMINATION: THE INFLUENCE OF THE PHYSIOLOGICAL CONDITION OF THE SEED UPON THE COURSE OF SUBSEQUENT GROWTH AND UPON THE YIELD. II. REVIEW OF LITERATURE. CHAPTER I.

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INTRODUCTION.

It may not always be fully realised to what a degree the developmental capacity of plants is pre-determined by the action of environmental conditions during the earliest stages of their life-histories. During the course of germination and in the seedling stage, or even earlier during the sojourn of the seed upon the parent and in the dormant period, the "potentialities" of plants may be affected by actions which only subsequently produce visible results. These results appear during the later stages of development, without reference to the conditions then existing. In this way adverse conditions in the later stages of development may not suppress a vigour of growth which has been pre-determined under favourable conditions during the ripening of the seed in

[1] *I.e.* the capacity of the resulting plant for growth and yield

the previous year; or favourable conditions during summer may fail to increase the yield owing to adverse conditions which have previously operated during the period of germination. It is such effects, namely those which are to be traced to the environmental conditions which have operated in the past stage of the plant's life, that we may term effects of physiological pre-determination in order to mark their distinction from those which are due to hereditary causes.

The present authors are engaged upon experimental work dealing with the effect of various conditions acting upon seeds during their maturation, dormancy, and germination in pre-determining the course of subsequent development and size of yield. Some preliminary results have been communicated in a previous paper (Part I of this series(44)); the present communication is a critical review of the literature bearing directly or indirectly on the problem.

It is interesting to note how exclusively attention has hitherto been concentrated upon the isolated question of germination in the enormous mass of literature dealing with the seed. In only a relatively small number of cases has experimental work with seeds included observations upon the subsequent course of development, nevertheless, the present review indicates clearly the wideness of the field and the possibility of obtaining important results if suitable experimental work on a sufficiently large scale be carried out both in the field and in the laboratory.

The most obvious categories under which we may deal with the conditions affecting the "potentiality" of the seed, meaning by this the capacity of the resulting plant for growth and yield, are as follows:

I. Parental conditions,
II. Harvesting conditions,
III. Conditions during, or immediately preceding, germination, or in the early stages of the seedling.

CHAPTER I

PARENTAL CONDITIONS AFFECTING THE "POTENTIALITY" OF THE SEED.

A. Soil, Locality, and Climate.

In considering cases which come under this category there is always the difficulty of excluding the possible operation of hereditary factors such as may make themselves obvious in the course of growth and development as differences between forms of the same species, but do not concern the question of physiological pre-determination.

That the environmental conditions of the parent plant and the position of the seeds on the parent plant affect the capacity of the seeds and produce obvious results in the course of their subsequent development has often been stated, but so far as we have been able to discern amongst the literature, no decisive investigation has been carried out on this subject. A number of indications are to be found, however, which make it clear that the question is one which would repay critical examination.

As is well known, traditions, of which we need not quote examples in detail, are common among farmers and seedsmen to the effect that the seed obtained from certain localities can be relied upon to produce a vigorous crop under normal conditions. Turning to experimental results, an interesting paper was read in 1904 before the Botanical Club of Washington by W. W. Tracy (70). He speaks first of leguminous plants. After stating that "Seedsmen commonly believe that, in the case of peas, the character of the soil has a marked influence over the character of the plant, and that this influence extends to and is carried by the seed, but that such soil influence is decidedly cumulative in its effects," he goes on to describe an actual experiment of his own, as follows: "In the case of garden beans, the tendency of rich, moist, heavy soil is to produce thick, fleshy pods slow to mature, while that of warm sandy land is to the production of flatter, less fleshy and quicker maturing pods. I can best illustrate this by experience. Some ten years ago I sent each of two growers living within a mile of each other, seed of 'Valentine' bean of precisely the same stock grown the previous year in the same field, which was a rich clay loam. One of these, whom I will call C., planted on rather heavy, rich soil, the other, S., on a light warm, but rich sandy one. The next season C. received seed grown by S. and S. seed grown by C., while a third man, M., some five miles away, on rich loam soil, received equal parts of both. When I visited the fields I noticed that in C.'s field, which I supposed was planted wholly with seed grown by S., there were ten rows which differed from the rest and were such as I would expect if seed from C. was planted, and I tried to account for them by extra manure, etc., but I learned that as there was not quite enough of the seed from S. sent him, he had filled out with some of his own, and I had detected the exact row where the seed was used. I then visited M. on loam soil, and while I could tell that one part of the field was planted with C. stock and the other with S., I could not detect the line between them."

De Vries (74) has emphasised as a result of his many years of experi-

mental experience the conclusion that external influences exert their effect on the development of organs during their youth, that is to say, during the so-called susceptible period. He finds that in many cases the most susceptible stage seems to be that of the young embryo in the ripening seed. It is in this stage that external conditions exercise a powerful pre-determining effect upon the whole subsequent course of the development of seed plants. He was led to enunciate two principles which we may quote fully in view of their importance.

1. "*The younger a plant is, the greater is the influence of external conditions on its variability, that is, on the place which its various characters will occupy in the curves of variability of the whole culture or race.*"

2. "*In connection with this principle the nutrition of the seed on the mother plant has, in many cases at any rate, a greater effect upon variability than nutrition during germination and vegetative life itself.*"

In an experiment with *Oenothera Lamarckiana*, after showing that the lengths of the fruits fall on a Quetelet-Galton frequency curve of variation and that a strong correlation exists between thickness of stem (taken as a criterion of vigorous development) and the mean fruit-length of the plant, De Vries shows that the effect of manuring the plant in increasing the mean fruit-length is not confined to one generation. He gave his plants similar manurial treatment for three generations, and his results are brought together in the following table:

Mean value for length of fruit:

After 1st year without selection	= 25·2 mm.
After 2nd year combined with positive selection	= 33·4 mm.
After 2nd year combined with negative selection	= 29·9 mm.
After 3 generations without selection	= 38·5 mm.

It is thus seen that the effect of high nutrition continued through a number of generations without selection proved itself superior to the most stringent selection, and even when combined with negative selection it improved the mean. The effect of manuring the parent plant was not confined to one generation. Under favourable nutritional conditions the parent plants produced embryos which were well-nourished during the "susceptible" period of seed-formation and the physiological condition of the seed thus produced pre-determined to a considerable degree the development of the plant produced after germination. It will be seen that this result is essentially the same as that obtained by Tracy. It shows, further, that the operation of high nutrition of the seeds is capable of accumulation through two or more generations, and the same is true of low or defective nutrition.

Harris (30 & 31) in a very elaborate statistical investigation has experimented in the opposite direction by submitting a race of beans (*Phaseolus vulgaris*) to recurrent starvation conditions for three generations in order to determine whether any accumulated effect was transmitted through the seed when the race was finally returned to normal conditions. His "starvation" conditions were obtained by growing the plants in fields in which the soil barely sustained the given species.

He arrived at the conclusion that statistical constants showed an unmistakable, though slight, influence resulting from the treatment of the ancestors upon the race when returned to normal conditions. He records this influence as mainly shown by a decrease in the number of pods per plant and in the number of ovules per pod, but by no modification in average seed-weight. The direct effect of the environment was of the same nature, but far more pronounced.

Gain (23) discussing the results of Raulin (60) concludes that a change in the chemical nature of the soil is favourable. Plants grown in different soils from generation to generation produce a larger average weight of seed than plants grown from generation to generation in the same kind of soil[1].

The results obtained by Raulin appear to be in contradiction to those of most other workers and to general experience with regard to cereals. Thus according to Hicks and Dabney (41), although a marked difference in crop is frequently noted when seed is transferred to a different type of soil from that in which it was grown, this difference is often in the negative direction. They state that (*l.c.* p. 308) "Experiments in growing oats have shown that certain varieties raised on a light soil were the most productive if sown on a similar soil, while the same varieties of seed, if grown on heavy soil, showed a preference for heavy soil."

With regard to the grasses, according to Tracy's (*l.c.*) experience, the character of the soil exercises little influence upon the character of the seed; climatic conditions acting upon the parent plant, however, have a marked effect upon the "potentiality" of the seed produced.

[1] "Il y a un maximum et un minimum d'influence correspondant à une certaine succession des divers sols (humus, sable, argile, calcaire).

Les *maxima* répondent, pour le Blé, aux changements suivants: graines cultivées dans l'humus, doivent venir de l'argile; celles destinées au sable doivent venir du calcaire; celles pour argile, du sable; celles pour calcaire, du sable.

Les *minima* répondent aux changements: graines cultivées dans l'humus, venant du calcaire ou de l'humus; en sable, venant de l'humus ou du sable; en argile, venant de l'humus ou de l'argile; en calcaire, venant du calcaire ou de l'humus."

"People who use large quantities of sweet corn are positive in their belief that seed produced in the eastern states gives better product than that grown at the west."

In a later communication by the same author ((71), p. 15) he says: "If a field of sweet corn is planted with two lots of seed of the same variety, one eastern and the other western grown, and ears as uniform as possible as to maturity and quality are gathered from the two parts of the field, processed, and canned in the same way, experts can with a fair degree of certainty decide which lot of seed the corn in different cans was grown from, and they will generally declare that the corn from eastern-grown seed is the better." Tracy's observations on the influence of climatic conditions upon Sweet Corn are confirmed by Duggar (17), who states that it is now recognised that Sweet Corn grown from the same seed from points north and south in the United States produces seed which when again sown side by side shows marked differences in that the seed from the north will produce plants that will mature earlier[1].

The best data on this question are due to T. Lyon (52). A variety of wheat was grown for several years in different localities, and finally in adjacent plots. The differences in date of ripening and in yield then observed are marked as is seen in the following table:

TABLE I.

Modification induced in Wheat by its Environment.

	Kanzas Seed	Nebraska Seed	Iowa Seed	Ohio Seed
Date of sowing	Sept. 9th	Sept. 9th	Sept. 9th	Sept. 9th
Lodged	None	None	Badly	Badly
Rust	Very little	Very little	Much	Much
Date of ripening	June 25th	June 27th	July 2nd	July 3rd
Yield of grain per acre ...	29·1 bushels	27·5 bushels	22·3 bushels	23·1 bushels
Weight of grain per bushel	64·2 lb.	62·2 lb.	56·9 lb.	58·9 lb.

The influence of the climatic environment of the parent plant upon the properties of the seed produced finds many illustrations in recent scientific works dealing with the question of seed germination alone, and has come to be regarded as a matter worthy of notice. For example,

[1] Quite recently Boerker (3) has contrasted seeds produced by *Pinus ponderosa* growing in the Rocky Mountains with the seeds produced by this tree growing near the Pacific coast. The seeds of the former are smaller and have a different capacity for germination. This botanist noted somewhat similar differences between the seeds of *Pseudotsuga taxifolia* from the Rocky Mountain and the Pacific coast regions respectively.

Kinzel (45) in his monograph on the influence of light upon seed germination emphasises the importance of the local origin of the seeds of *Poa pratensis* with regard to their light-sensitiveness in germination. His numerous experiments with seeds of *Poa pratensis* from different regions show that every degree of light-sensitiveness may exist independently of after-ripening, which occurs during storage. Seeds from plants of the same original stock growing in different regions, when tested, showed various degrees of light-sensitiveness in their germination. In one case Kinzel (*l.c.*) with *Poa pratensis* was able to show that, even in the same locality, different climatic conditions during maturation exert a marked effect upon the light-sensitiveness of the resulting seeds. Seeds from the crop matured in bright sunny weather at Munich in 1906 showed themselves extraordinarily sensitive to the deleterious effect of blue light; on the other hand, the seed-crop from the same original stock of seed matured in dull rainy weather at Munich the following year showed scarcely any sensitiveness to the harmful effects of these rays.

Ottenwälder (58), working on the effect of light on germination of seeds of *Epilobium hirsutum* and other plants, found that the age and origin of the seeds modified his results considerably.

The environmental conditions which obtain during the maturation of the seed are undoubtedly of great importance (cf. Von Lochow (48)). Excessive moisture may hinder the gradual ripening processes and thus affect the conditions under which food-reserves are stored in the seed, and such effects may become evident in the plants produced from these seeds. Duggar (*l.c.*) mentions these possibilities, but critical work on the subject seems to be non-existent.

It is possible that the effects of soil and climate resolve themselves into a question of the degree of maturity reached by the seed at the time of harvesting.

B. Size of Seed as an Index of Parental Conditions affecting "Potentiality."

Under this first category of parental conditions and their effect upon the capacity of the seed for producing plants of greater or less vigour, we deal next with the influence of the size of the seed upon the resulting plant. This question has received more attention by both practical and scientific workers than the less obvious, but equally important, factors alluded to above.

It is obvious that any sample of seed can be graded according to

size; this is a common practice in seed selection, water-culture experiments, etc., and in scientific work generally. The main conclusion to be drawn from the available evidence, to which we shall allude immediately, concerning the selection and use of seed of different size, both in the case of forest-trees and in the case of herbaceous plants of economic importance, is distinctly in favour of the general conclusion that large seed produces a more vigorous crop and larger yield, although important contradictions to this statement have been published.

In view of its importance in practice it is essential in considering this question to analyse the conditions which affect the size of the seed. The latter may depend either upon the environmental conditions of the parent plant, or upon the position of the flower on the inflorescence and of the inflorescence on the plant, or upon a hereditary factor.

In experimental work planned to determine differences in crop production arising from the selection of seeds of different size there has usually been no distinction drawn between the various causes influencing the size of the seed. This failure has introduced some confusion into the interpretation of the results which have hitherto been obtained in research work on this subject. If we are dealing with a hereditary factor for large seed, the average weight of seed in the crop, but not necessarily the total weight of the crop (cf. Waldron(75)), would probably be pre-determined by heredity, and the question with which we are dealing, namely, a question of physiological pre-determination, would not come in.

(*a*) *Determined by Climatic and Edaphic Factors acting upon the Parent Plant.*

When the size of the seed is altered by climatic or edaphic factors acting through the parent plant, any resulting increase or decrease in yield from the seed thus altered can only be a matter of physiological pre-determination.

The literature bearing on this question is very scanty: The effect of various light-intensities upon seed-formation and the size of seeds has been subjected to investigation by Combes(11). He tested the germination capacity of the seeds of different sizes which he obtained by differential treatments of the parent plants. His plants were grown for the whole period of their existence under five intensities of light obtained by glass screens of various thicknesses which gave $\frac{1}{9}$, $\frac{1}{3}$, $\frac{1}{2}$, $\frac{3}{4}$, and 1 of the total insolation as determined by Wiesner's method.

The following table gives both the air-dry weight and the absolute dry-weight of 1000 seeds ripened in each case.

TABLE II.

Light-intensity ...	$\frac{1}{9}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{3}{4}$	1
Cannabis sativa ...	*20·2**	**22·1†**	*20·4*	*17·8*	*16·5*
	176	199	187	161	146
Saponaria officinalis ...	—	—	**1·87**	*1·83*	*1·59*
	—	—	162	157	135
Sinapis arvensis ...	—	—	—	**2·19**	*1·58*
	—	—	—	199	141
Amaranthus retroflexus	—	*·348*	*·443*	**·447**	*·422*
	—	303	376	380	352
Chenopodium album ...	—	**·752**	*·696*	*·680*	*·671*
	—	630	594	578	570

* Calculated from three achenes, all that were produced from 1000 plants.

† Calculated from 600 achenes.

It is seen that the largest average seed-weight is never obtained in full light, but with *Cannabis sativa* in $\frac{1}{3}$ light, with *Saponaria officinalis* in $\frac{1}{2}$ light, with *Sinapis arvensis* in $\frac{3}{4}$ light, with *Amaranthus retroflexus* in $\frac{3}{4}$ light, and with *Chenopodium album* in $\frac{1}{3}$ light.

This somewhat striking result shows that the largest seeds are produced under conditions of light-intensity which are only just sufficient to allow the production of fruit at all, *i.e.* with the minimum light intensity. The case of *Cannabis sativa* illustrates this point very clearly; the maximum average weight of single achenes was obtained in $\frac{1}{3}$ light, as stated above; in $\frac{1}{9}$ light only two out of 1000 plants produced achenes, to the number of three in all. The average weight of these, however, falls only very little short of the average weight of those obtained in large numbers with $\frac{1}{3}$ light[1]. The seeds from Combes' harvest were tested for germination; in result it was found that the highest percentages of germination were obtained with seeds developed under light-intensities which were most favourable for the production of large seeds, in other words, the heaviest seeds gave the highest percentages of germination[2].

It is to be expected that many other environmental conditions acting through the parent plant would greatly affect the size of the seed

[1] The number of fruits per individual plant and the number of seeds per fruit diminish from the full light to 1/9 light.

[2] Similar results have been obtained for twelve different species of economic and garden plants by Lubimenko (50), who, however, only submitted fruits during their development to different light-intensities.

Under this heading attention must be drawn to the observations of Boerker (2) mentioned above (p. 117, footnote).

produced, but we have been able to trace few critical published results bearing upon this point.

The results of investigations by J. L. Jensen(42) indicate that the average grain-weight of cereals is clearly related to climatic conditions. In brief, the average grain-weight decreases as the continental character of the country becomes more marked and, *vice versa*, it increases with an insular or coast climate, and in connection with such climate it also increases with rising temperature. In the following table the average weight in grams of 10,000 grains is given for wheat, barley, oats, and rye respectively from each country investigated:

TABLE II *a*.

Grain-weights according to climatic conditions.

Group	Countries	Average weight in grams of 10,000 grains.					
		Wheat	Barley	Oats	Rye	Average	Ratio
1	Russia	244	333	245	178	250	100
2	U.S.A.	346	347	253	194	285	114
3	Germany	353	399	302	231	321	128
4	Denmark, Norway, Sweden ...	354	410	322	244	332	133
5	Great Britain, Holland, Belgium...	405	440	311	266	355	142
6	Italy, Spain, France	468	465	329	295	389	156
Average for continental climates... ...		314	360	267	201	—	—
Average for insular and coast climates ...		409	438	321	268	—	—

Such records as the following, however, occur. Raulin(60) grew varieties of wheat at Lyons and in the Ardennes for comparison. The crop ripening at Lyons was planted the following year in the Ardennes, and *vice versa*, for several years. The conclusion drawn was that "les poids de 100 grains paraissent tendre à Lyon et dans les Ardennes d'année en année, vers des limites différentes: inférieure à Lyon (Pierre-Bénite), supérieure dans les Ardennes."

The interesting indications provided by Combes' work that environmental conditions which result in a weak or a slow development of the parent plant may be correlated with the production of larger seeds though fewer in number, find confirmation in a series of statistical studies by Waldron(75) and Harris(39). Waldron (*l.c.*) found in the case of oats a strong correlation between short culms, short heads and small number of grains on the one hand, and heavy-seededness on the other. On the basis of some data of Lyon's he worked out for wheat a similar, but less marked, negative correlation between the number of grains per head and

size of the grains. Harris (*l.c.*) found in the case of *Phaseolus vulgaris* that the weight of the seeds increased in relation to the percentage of ovules which failed to develop.

Von Lochow (48), working with rye plants of the same origin, showed that the average grain-weight was higher for the plants with spikes incompletely filled with grains than for those with spikes completely filled with grains, the proportions being 39 : 32·5; but that the total yield of grain was considerably in favour of the latter, the proportions in this case being 72·5 : 90. As a result of his experience Von Lochow made the interesting observation that heavier seed of unknown ancestry might be inferior to smaller seed of the same origin.

Owen (59), as a result of five seasons' work with beans, found that by limiting the yield of the plant to one pod the weight of the seed was greatly increased, so that the question still to be answered is whether it is not the number of seeds developing that controls their average size even in such experiments as those of Combes quoted above.

(*b*) *Determined by the Position of the Seed in the Fruit, of the Fruit on the Inflorescence, and of the Inflorescence on the Plant.*

Where the size of the seed is obviously mainly controlled by its position on the parent plant, the presumption is that differences obtained by the use of seeds of different size are to be accounted for by physiological pre-determination.

Several recent authors have worked out on a large scale correlations between seed-size and the position of the seed in the fruit and on the inflorescence, and of the inflorescence on the plant. Halsted and Owen (28) found that the heaviest seeds of Scarlet Runner beans occur in the three-seeded pods and in the middle position in these pods; two-seeded pods and seeds from the basal position give the smallest average weight, nevertheless seeds from the two-seeded pods show the greatest average germination percentage and the greatest average weight of seedling per plant[1]. This result points to a correlation between vigorous growth and seeds of *small size*, which would appear to be one of physiological pre-determination, but unfortunately these experiments were not carried far enough to enable one to decide this point with certainty.

[1] Cummings (12) observed that in beans 49 per cent. of the small seed were found to occur in the basal end, while 18 per cent. occurred in the middle of the pod. In the case of garden peas the small seeds were almost always found at the ends of the pods, with one end as prolific as the other.

Halsted(26 & 27) shows that with Soy Beans the size of the seed is controlled by the number of seeds in the pod and by their position in the pod. The basal seeds and the seeds in one-seeded pods are the heaviest, but these produce the poorest plants. According to Halsted the seeds which occur in the middle position in the pod give the most vigorous plants.

Working with *Phaseolus vulgaris* J. A. Harris(36, 37, & 39) found that a correlation existed between the number of seeds in a pod and the seed-weight, and that the seed-weight is influenced by the position of the seed in the pod. In an earlier study with the same species Harris(29) found that seeds of *medium weight* are more capable of developing into fertile plants than those produced from the larger or smaller seeds of which the weight exceeds or falls below the average. With regard to germination, however, this observer(30) states that the larger the seed the longer it takes to germinate.

The same author(32), working with *Staphylea*, obtained indecisive results.

In the sugar beet two to five or more fruits are associated to form a so-called "clump." In this "clump" the upper flower produces the largest seed, the lateral seeds are markedly smaller. Briem(5) has conducted a series of experiments to determine what effect the difference in seed-size has upon the subsequent plant and its yield. He sowed the individual seeds of a "clump" separately and compared the resulting plants with one another throughout the whole course of their development. The largest seed produced the largest seedling, the finest beet, and lastly, the most fertile seed-parent. The figures for the relative weights of five seedlings of a "clump" in one case were 100, 74, 67, 51 and 46 respectively. The full-grown beets derived from a single "clump" weighed 1156, 859, 574, 344, and 310 grams and furnished respectively 241, 167, 202, 239, and 104 grams of seed at the end of their second year. Townsend and Rittue(69) found that sugar-beet plants produced from "single-germ" seeds, which appear to be strictly localised on the parent plant, not only gave a higher (about 30 %) percentage of germination, but were more vigorous and possessed greater vitality than those produced from the so-called "multiple-germ" seeds.

In a classical experiment many years ago Nobbe(57) showed in the case of wheat and barley that variation in the size of the grains on the ear is correlated with their position on the ear. A random distribution, such as would occur if genetic factors were concerned, does not occur. The largest grains occur in the middle-length of the ear. In the same

experiments it was shown that the most vigorous plants are the outcome of the largest seeds.

In view of what follows with regard to the large amount of experimental work that has been carried out with cereals with the object of improving the yield obtained by the selection of large seed, and in view of the emphasis which has been laid for the most part in this work on the assumption that the authors were dealing with genetic factors in their selection, the importance of Nobbe's results justifies the quotation of his table in full:

TABLE III.

	BARLEY		WHEAT	
No. of 3-seeded spikelet (from base of ear upwards)	Air-dry weight in milligrams of the 3 seeds of spikelet (after removal of the awn)	Total root-length in millimetres of seedlings produced from the 3 seeds after 5 days in a germinator	Air-dry weight in milligrams of the 3 seeds of spikelet	Total root-length in millimetres of seedlings produced from the 3 seeds after 5 days in a germinator
1	0 mg.	0 mm.	0 mg.	0 mm.
2	1·5	0	0·5	0
3	2·5	0	0·8	0
4	55·5	144	17·7	48
5	67·5	121	22·5	40
6	79·5	102	26·5	34
7	90·5	90	30·2	30
8	72·5	90	24·2	30
9	92·5	123	30·8	41
10	103·5	532	34·5	177
11	95·5	294	31·8	98
12	97·5	464	32·5	132
13	95·5	273	31·8	125
14	97·5	299	32·5	100
15	92·0	311	30·7	104
16	92·5	335	30·8	112
17	86·5	367	28·8	155
18	87·0	397	29·0	91
19	81·5	140	27·2	47
20	81·5	129	27·2	43
21	74·5	190	24·8	63
22	74·5	118	24·8	39
23	66·5	273	22·2	91
24	47·5	216	15·8	72
25	26·5	96	8·8	32
26	27·0	63	9·0	21
27	32·5	139	10·8	46
Average	71·5 mg.	221·5 mm.	23·3 mg.	77·5 mm.

The above results are summarised in the following table:

TABLE IV.

No. of spikelet (from base of ear upwards)	No. of seeds	Barley: Total air-dry weight in milligrams of seeds	Barley: Total root-length in millimetres after 5 days in germinator	Wheat: Total air-dry weight in milligrams of seeds	Wheat: Total root-length in millimetres after 5 days in germinator
Spikelets 1– 9	27	426 mg.	670 mm.	153 mg.	223 mm.
,, 10–18	27	828	3281	282	1094
,, 19–27	27	512	1364	191	454

It is unfortunate that Nobbe's experiments were not carried further to determine whether the plants which he obtained from his larger seed would continue to show throughout their development a superiority over those obtained from the smaller seed and would finally produce a larger yield. This point, however, has since been investigated by Bolley and by Richardson and Green. Bolley(4) in the course of a series of experiments extending over four years to test the difference in yield when plump grains of large size and plump grains of small size were selected for seed, found that "perfect grains of large size and greatest weight produce better plants than perfect grains of small size and light weight, even when the grains come from the same head."

Richardson and Green(62) carefully analysed a large number of heads of wheat and found the heaviest grains in the middle of the ear. They found, however, a complication due to the fact that the median grain of each spikelet tended to suffer in its development with the result that the median grains were almost always lesser in weight and, if they happened to germinate, gave rise to inferior plants.

The following table gives their results in comparing both percentage of germination and yield for the heavier grains from the central region of the ear with that for the lighter grains from the tip and base of the ear together with the *median* ones from the central region.

TABLE V.

Comparison of Yield of Produce from median* *grains together with the light grains at either extremity of the head with that from heavy grains.*

Group	Treatment	Number of grains taken	Average weight of seed	Percentage unproductive	Average weight of ears produced per plant
1	All *median* grains and grains under 35 milligrams	38	27·9 mg.	16 %	1·81 gms.
2	Grains over 35 milligrams	80	43·5 mg.	4 %	2·86 gms.

* *I.e.* the seed which occupies the median position in the spikelet.

Other investigators who have dealt with the effect on the size of seed of their position on the parent plant in the case of cereals and whose results confirm those of Nobbe may be mentioned. Von Rümker (63)[1] in the case of wheat showed that the heaviest grains on the inflorescence occur on the lower half of the spike while Fruwirth (21) showed that the heaviest grains of Barley, Rye, Wheat, Spelt, and Maize, are situated at the middle or somewhat below the middle of the ear (cf. also Wenholz (80)). Bruyning (6) found that the lower grains of the lateral ears are the best in the case of oats[2].

Halsted (26) has recently shown that seeds of corn taken from the middle of the ear produce more vigorous plants than those taken from the base, whilst those from the base are better again than those from the tip of the ear. Walls (77) in 1905 found that a strong relationship existed between the size of the germ and the vigour of the resulting plant and that this vigour continued throughout its life-history. He also found that the plants from the grains with the largest germs were better able to withstand drought.

(c) *Experiments in which the Factors controlling the Size of the Seed are undetermined.*

A large number of experiments have been conducted chiefly with cereals to determine the difference in yield obtained when selected large and selected small seed are used for comparison. The balance of evidence is in favour of the conclusion that more vigorous plants and better yields are obtained by the use of heavy seed. The chief difficulties to be encountered in interpreting these results from the point of view of their significance as evidence of physiological pre-determination lie first in the possibility of hereditary factors for seed-size being concerned, and secondly in the fact that in field experiments on the basis of the data given it is not possible to compare yield *per plant*.

In the case of cereals the presumption has usually been that the experimenter is concerned with a hereditary factor, but, as we have already indicated, the fact that the size of the seed appears to be almost entirely controlled by its relative position on the ear militates strongly at the outset against this view. Further, in most experiments continued over several years with continuous selection of large and of small

[1] In contrast to Waldron, von Rümker found in the case of wheat that the average seed-weight increases with the size of the spike.

[2] As long ago as 1830 Girou de Buzareingues (9) stated that in the hemp the largest seeds occur in the middle region of the inflorescence and give rise to the largest plants.

grain, the great divergence in yield is almost always observed only in the first year (see Desprez(15), Lyon(51), also Soule and Vanatter(67)), whereas if a hereditary factor for seed-size is concerned, it should take many years to segregate it by selection since it would be in any case almost completely masked by the effect of position upon the seed-size.

Waldron's (*l.c.*) statistical results with oats indicated that, if any hereditary factor were involved in the selection of large grain, the size of the individual grain might be increased, but the total yield would probably be decreased. For in all populations examined, he found a strong correlation between large-seededness and weak development, *i.e.* small size of plant combined with small yield in number of grains. As in nearly all experiments with cereals an increased yield has been observed following the use of large grain, but in very few cases has any increase in the average size of the grain been noted, the obvious presumption is, therefore, that increased yield is due in the main to physiological, and not to hereditary pre-determination. Waldron concluded that if plants from larger grains produce a better yield, then they must do so by virtue of the increased vigour of the embryo and the increased amount of food-material available.

When the crop is a leaf crop, the correlation between large-seededness and yield may in all probability be safely put down to physiological pre-determination.

The second difficulty that is encountered when considering the results of many large-scale field experiments is that we cannot definitely decide how far they are due, not to differences in the vigour and yield of individual plants, but to differences in number of plants.

In many experiments the sowing has been carried out at the bushel-acre rates and no determination has been made of the relative number of grains per bushel, so that the real rate of sowing with regard to number of grains per given area is not the same with the large and small seed respectively, but is in favour of the latter.

In the second place a difference in germination capacity between light and heavy seed will introduce an unknown error from this point of view. A. Müller(55), who experimented with oats, wheat, and rye, found, for example, that the heavier grains gave a higher percentage of germination and produced larger seedlings than the lighter grains. The light seeds of oats gave 68 per cent. germinations in eleven days whereas the heavy seeds gave 92 per cent. germinations in the same interval (see also Grenfell(25), Boerker(3), Shamel(65), Lehmann(47), Vandevelde (72), Webber and Boykin(78), Eisenmenger(20), and Hicks and Dabney(41)).

The question of probable error in agricultural experiments is also important[1]. Thus Soule and Vanatter (67) working with wheat carried out an experiment for three years with continuous selection and found an average difference in yield at the end of three years between large and small grains of 5·18 bushels per acre in favour of the large grains, but when the experiment was continued on different plots in the two following years the divergence in yield was no more than 0·32 bushels per acre in favour of the large grain.

In quoting results of various workers with regard to the better yield obtained by the use of large seed we will confine ourselves as far as possible to those in which equal numbers of light and heavy seeds have been sown.

The following are some of the results obtained by C. A. Zavitz (82) (Table VI). He selected seeds of three grades, viz. large, medium-sized, and small. For grade I none but well-developed grains of large size were selected; for grade II the grains selected were of uniform character, plump, and of medium size; while for grade III none but sound, plump, and apparently good seeds of small size were used. In the selection of large plump grain ½ lb of each class was carefully weighed and counted and a corresponding number was then taken of the medium-sized and of the small plump grains. The different selections were sown upon plots of similar size.

TABLE VI.

Crop	Number of years of tests	Yield of grain per acre from Grade I Large seed	Grade II Medium-sized seed	Grade III Small seed
Oats	7	62·0 bushels	54·1 bushels	46·6 bushels
Barley ...	6	53·8	—	50·4
Spring wheat	8	21·7	—	18·0
Winter wheat	6	46·9	—	40·4

Zavitz (82) continued these experiments for several years, each year selecting his seed from a common stock of grain sown in the Ontario Experimental Station Farm in the manner described above. The averages of the results thus obtained are tabulated below.

Zavitz believed that in selecting heavy seed and obtaining from it a bigger yield he was dealing with a hereditary factor, either for vigour or for size of seed. In an experiment with oats continued for 13 years with continuous selection he (83) selected his seed for size, plumpness,

[1] "The Interpretation of the Results of Agricultural Experiments." *Suppl. to Journ. Board of Agric.*, London, Nov. 1911.

Table VII.

Kind of grain	Number of years test was repeated	Selections	Weight of grain per measured bushel	Average yield per acre (from 5–8 years)	
				Tons of straw	Bushels of grain (by weight)
Barley ...	6 years	Large plump seed	49·5 lbs.	1·5	53·8
	6	Small plump seed	48·8	1·5	50·4
Spring wheat	8	Large plump seed	59·1	1·4	21·7
	8	Small plump seed	58·3	1·3	18·0
Winter wheat	5	Large plump seed	59·5	2·4	42·4
	5	Small plump seed	59·3	2·0	34·8
Oats	7	Large seed	33·2	1·9	62·0
	7	Medium-sized seed	32·2	1·8	54·1
	7	Small seed	31·8	1·8	46·6

and dark colour on the one hand, and for light weight and light colour on the other. Equal numbers of seeds of the heavy and light samples were used for the yield tests. We may quote his final results obtained in the thirteenth year. "The large plump seed produced 65·5 bushels, the light seed 44·7 bushels per acre." In this year the average size of the seed from the crop produced by the large plump seed was greater than that from the crop produced by the light seed. In the first case it required 1149 seed-grains to weigh 1 oz. and in the second case 2066.

In this experiment it will be seen that Zavitz, in contrast to most other workers, records a marked increase in average size of grains as well as an increase in total yield. If plants from large grains are more vigorous and produce a larger yield as a result of physiological pre-determination an increase in the average size of the grains yielded would also probably occur[1], but in these results of Zavitz's it seems more probable that hereditary factors are concerned. We have to note the large number of years over which the experiment was continued and which would allow time for the slow separation of a possible hereditary factor for large-seededness. As has been pointed out, selection for seed-size would have little effect in one generation owing to the fact that seed-size as an hereditary character would be almost entirely masked by the influence upon size of the position of the seed upon the parent plant, so that in a first separation of large and of small seeds the sample of large seed would probably only contain relatively very few more seeds large by heredity than the sample of small seed. In the second place his selection was not

[1] Desprez (15) with wheat found that the use of large seed gave a crop with grains larger than those grown from small seed. In Lyon's (51) work this was also noted.

confined to size of seed, but was also made on the basis of colour-differences such as are known to be often associated with hereditary factors.

We may turn now to an author who has conducted careful experiments with wheat in which equal numbers of small and of large grains were sown and in which the percentage of plants that grew was determined. Grenfell(25) describes his selection as between plump and shrivelled grains. These were sown in alternate rows, 150 grains to a row. He notes in the first place that the plants from the plump grains soon began to get a start of the others and kept ahead all through. The percentage of plants that grew from the plump grains was also in excess of that from the shrivelled. The following table gives his results from which it appears that the average yield per acre from plump seed-grain is 9·8 bushels as opposed to 7·5 bushels from shrivelled seed-grain.

TABLE VIII.

Variety of seed	Kind of seed	Percentage of plants that grew	Number of heads	Tillering power	Average yield in bushels per acre
Steinwedel	Plump	96·0	179	1·24	10·9
,,	Shrivelled	89·3	174	1·29	9·9
Purple Straw	,,	89·3	153	1·14	6·1
,,	Plump	90·0	200	1·49	10·0
,,	Shrivelled	76·0	140	1·16	6·9
,,	Plump	92·0	161	1·23	8·4
,,	Shrivelled	98·0	155	1·34	7·2
Plump-kernel averages ...		92·7	180	1·32	9·8
Shrivelled-kernel averages		88·5	155	1·23	7·5

From the point of view of physiological pre-determination the sort of difficulty involved in interpreting his results and the results of many other authors who have worked on the same lines with cereals, is clear; obviously the number of plants that grew and the amount of tillering per plant, which combined give the number of heads per seed sown, greatly affect the results[1].

From Grenfell's figures, however, we are able to work out the relative yield *per head* and the relative yield *per plant* from plump and shrivelled seed respectively.

[1] Driesdorf (*Zeitsch. f. d. Prov. Sachsen*, 1868) observes that in April winter wheat from large seed-grain showed greater tillering and a deeper green colour than that produced from small seed-grain.

TABLE IX.

Relative yield per head		Relative yield per plant	
Plump grains	Shrivelled grains	Plump grains	Shrivelled grains
50	57	113	111
61	46	111	68
52	40	91	91
—	49	—	73
Average = 54·3	Average = 48	Average = 105	Average = 86

The figures indicate, not only that the yield per plant from heavy seed is greater (about 20 per cent.), but also that the yield per head is greater independently of the tillering, which, if anything, is also greater in the plants from plump seeds.

Edler (18 & 19) carried out experiments with seeds weighing 50·9 and 33·9 gms. per 1000 respectively. In one test the same number of grains of the heavy and of the light seed were sown. It was found that the heavy seed produced the heavier plants, having a larger number of productive stems and producing heavier and a larger number of grains than plants from the light seed.

Before leaving the case of cereals a brief reference must be made to various other authors whose results, although they cannot be critically interpreted from the point of view of physiological pre-determination, make it clear that from the practical point of view the balance of evidence, as we have said before, is in favour of the use of large seed[1].

Author	Description of experiments	Average yield of seed-grain
Sanborne et al. (64) ...	4 years' continuous selection of large and shrivelled grain of wheat	7·47 bushels per acre in favour of the *heavy* grain
Latta (46)	3 years' discontinuous selection of heavy and light wheat grains separated by a fanning mill	2·5 bushels per acre in favour of the *heavy* grain
Georgeson et al. (24) ...	3 years' discontinuous selection of light and heavy wheat grain	1·88 bushels per acre in favour of the *heavy* grain
Desprez (15)	3 years' continuous selection of large and small grain of five varieties of wheat	761 kilograms per hectare in favour of the *large* grain
Dehérain et Dupont (13)	Experiment extending over a single year with large and small grain of five varieties of wheat	150 kilograms per hectare in favour of the *large* seed
Hickman (40)	9 years' continuous selection of large and small grain of wheat	0·25 bushel per acre in favour of the *small* grain

[1] Many other workers have obtained similar results; for example, Cobb (10), Bolley (4), Lyon (51), Blanchard (2), and Richardson (61) with wheat; Dietrich (16), Buckmann (7), Sorauer (66), and Welton and Gearhart (79) with oats; Lubanski (49) with winter wheat, barley, and oats; and Von Lochow (48) with rye.

Author	Description of experiments	Average yield of seed-grain
Voelcker (73)... ...	Woburn pot-culture experiments with wheat and barley (1900–4). (The Hill's experiments)	Yield very slightly in favour of the *small* grain
Nielsen (56)	Experiments with rye extending over 10 years	
	I. Using equal numbers of large and small grains	I. Very slightly in favour of the *large* grains
	II. Using equal weights of large and small grains	II. No marked difference in yield

In conclusion we may quote the results of Hicks and Dabney (41) with cereals, which show clearly the effect of seed-weight upon vigour, although the experiments are not carried further than the seedling stage. They found similar results with Vetch, Sweet Pea, and Radish.

TABLE X.

Experiments with Heavy and Light Seeds.

Name and variety	Number of seeds in each lot	Weight of seeds* in grams	Number germinated	Number of plants weighed in each lot	Number of days of experiment	Weight of seedlings in grams
Kaffir Corn (red)	100	A. 3·298 B. 1·741	A. 90 B. 49	47	39	A. 22·0 B. 13·0
Rye (University of Minnesota, No. 2)	50	A. 1·105 B. 0·745	A. 45 B. 45	45	23	A. 34·5 B. 20·0
Oats (White Wonder)	50	A. 1·298 B. 0·805	A. 50 B. 49	49	23	A. 37·2 B. 25·0
Barley (Salzer's)	50	A. 2·522 B. 2·146 C. 1·496 D. 0·957	Not recorded	Equal number of each lot	19	A. 39·5 B. 34·5 C. 29·0 D. 23·0

* A, heavy seed; B, lighter than A; C, lighter than B; D, lighter than C.

Leaving cereals upon which most of the work dealing with differences in yield resulting from the use of large and small seed has been carried out, a few results may be quoted which show that the same fact, namely, that more vigorous plants giving a bigger yield of leaf- and seed-crop result from large seeds than from small, holds generally good in the case of plants belonging to other families.

As early as 1869 a very complete series of results was obtained by Lehmann (47) for peas. He showed that the capacity for germination was greater in the case of the large seeds, but that, independently of the percentage of germination, the yield per 100 plants from heavy seed greatly exceeded that from the same number of plants from light seed.

TABLE XI.

Kind of seed used	Weight of 100 seeds	Number of seeds used	Number of plants obtained from 528 seeds
Peas (small seed)	160 gms.	528	423
Peas (medium-sized seed) ...	221	528	478
Peas (large seed)	273	528	480

	Yield from 100 mature plants			
Kind of seed used	Seeds	Pods	Stalks	Total weight in gms.
Peas (small seed)	236 gms.	66 gms.	475 gms.	777 gms.
Peas (medium-sized seed) ...	313	75	550	938
Peas (large seed)	378	91	660	1129

He further showed that a better yield was obtained from a given weight of heavy seeds than from the same weight of light seeds in spite of the fact that nearly twice as many plants were obtained in the latter case, thus emphasising the fact that from the point of view of the agriculturalist it is advantageous to use large seed.

TABLE XII.

Results obtained from 188 *grams of each kind of seed sown in plots* 8·5 *metres square.*

			Weight of grain	
Kind of seed used	Number of seeds sown	Plants developed	per 8·5 sq. m.	per 100 plants
Peas (small seed) ...	780	680	1590 gms.	234 gms.
Peas (medium-sized seed)	530	505	2224	440
Peas (large seed) ...	384	360	2307	640

In view of Lehmann's results reference must be made to Johannsen's (13) work with beans. Taking a mixed sample of seeds of a single variety of *Phaseolus*, he obtained a simple Galton frequency curve for their weights. As a result of sowing the large seeds he found that the plants produced (self-fertilised) showed a shifting of the modal weight in the direction of large-seededness. Similarly, when small seeds were chosen, the modal weight of the crop obtained from them was found to be smaller than that of the original sample. But when the same experiment was repeated with any one family (*i.e.* the crop raised from a single seed), selection did not alter the modal weight.

Johannsen's results might have an application in interpreting those of Lehmann: it is to be noted, however, that in Lehmann's experiment the data do not allow one to determine whether there was any increase or decrease in the average seed-weight. It is also to be noted that he remarks that the plants from the smaller seeds were less well-developed

and less productive than those from the larger seed. His figures for weight of pods and stalks indicate this clearly.

Some recent work by M. Delassus(14) strongly favours the inference drawn that Lehmann's results are largely due to physiological pre-determination. Delassus worked with *Vicia Faba*, *Vicia sativa*, *Lupinus albus*, *Cicer arietinum*, and *Zea Maïs*. We quote the results he obtained with *Vicia Faba*.

Forty large and 40 small seeds were chosen from the same source and subsequently received exactly similar treatment. The seedlings were grown "en pleine terre"; "dans un sol n'ayant reçu aucune fumure pendant l'année courante de façon à rendre plus sensible encore l'action des réserves de la graine." From the very beginning of germination marked differences were observed and distinct morphological differences manifested themselves throughout the development of the plants produced. In comparison with the plants produced from the sample of large seed those produced from the sample of small seed show a retarded vegetative development which is obvious in the number and dimensions of the leaves and leaflets produced (Table XIII). The root system is also adversely affected in the case of the plants from the small seeds.

TABLE XIII.

The Influence of Seed-size upon the Development of the Resulting Plant in the case of Vicia Faba.

	After 1 month's growth		After 2 months' growth		After 3 months' growth	
	Lot I*	Lot II*	Lot I	Lot II	Lot I	Lot II
Growth of plants in millimetres	171 mm.	146 mm.	408 mm.	323 mm.	664 mm.	528 mm.
Number of leaves produced	7·7	6·6	48·7	34·6	96·0	78·0
Number of leaflets produced	19·1	15·1	154·5	112·6	386·0	308·0
Breadth of leaflets ...	48·0 mm.	39·9 mm.	47·0 mm.	40·7 mm.	—	—
Length of leaflets ...	71·9 mm.	59·8 mm.	75·9 mm.	67·1 mm.	—	—
Dry weight of five samples dried at 100° C. for 10 hours	5·577	3·428	9·20	5·58	29·3	20·5

* Lot I = plants from large seeds; Lot II = plants from small seeds.

It is also to be noted that the number of flowers produced is greater in the plants from the large seeds and that these flowers give rise to more numerous and larger fruits than those of the plants from small seed.

Striking anatomical and histological differences also become evident. Thus, a greater development of xylem and phloem elements and especially of stereome (*i.e.* sclerenchyma and collenchyma) occurs in the case of the plants produced from large seed.

This work of Delassus exactly confirms the results of detailed experiments reported by Hicks and Dabney (41) in 1896, who compared large and small seeds of Soy Beans and Garden Peas respectively. The seeds were planted in pure sand in a greenhouse, equal amounts of a culture solution which contained all the elements necessary to plant growth being

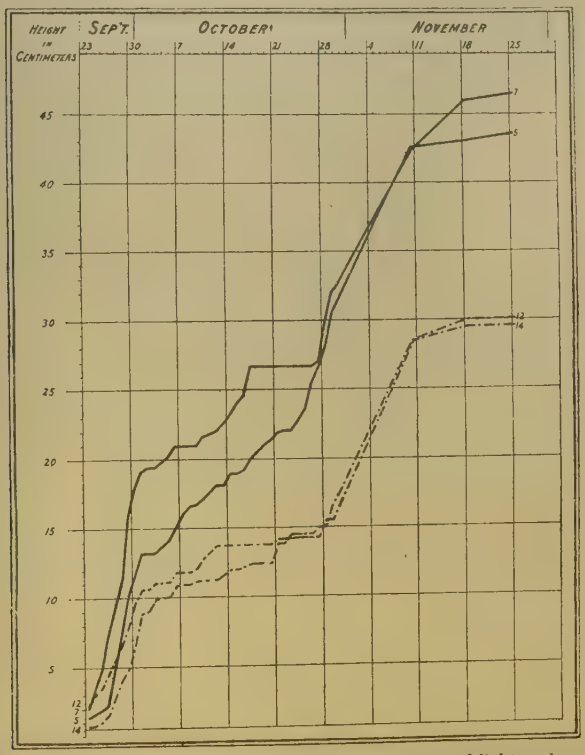

Fig. 1. Curves showing development of Soy Beans from heavy and light seed respectively. The upper curves represent plants from heavy and the lower those from light seed. (After Hicks and Dabney.)

given to the plants, which were kept from first to last under identically similar conditions so far as possible. In result they found that the large seed produced plants which gained continually upon those from the small seed and finally gave larger and more vigorous plants and a better yield as is shown by the curves represented in Figs. 1 and 2.

In the case of the peas a further important advantage is gained by the selection of large seed, namely, increased earliness (see Fig. 2).

Burgerstein (8) has very thoroughly worked out the case for *Phaseolus vulgaris*, var.; the following table summarises his results:

TABLE XV.

Yield from Small Seeds compared with the Yield from Large Seeds taken as 100*.

Kind of seed used	Number of seed-bearing pods	Number of harvested seeds	Weight of harvested seed in mg.	Relation of average weight A. of the harvested seed Large : Small	Relation of average weight B. of the seed sown Large : Small
1. Flageolet ...	99	82	76	100 : 93	100 : 50
2. Niger	72	70	58	100 : 84	100 : 46
3. Non plus ultra ...	96	98	96	100 : 98	100 : 59
4. Osborn	96	99	91	100 : 92	100 : 56
5. Spargel	92	96	86	100 : 89	100 : 57
6. Wiener Zweig ...	88	72	68	100 : 95	100 : 78

* The plants produced from the small seeds ripened by the 16th of August, those produced from the large seeds by the 22nd of August.

From the above table it is seen that the bean plants produced from very small seeds gave rise to seeds which were only slightly smaller than those which under similar conditions were produced by plants from very large seeds. Statistical work by Harris (34, 35, & 38) has since confirmed Burgerstein's results. Harris found that in the case of *Phaseolus vulgaris* the number of pods and also the number of ovules and seeds per pod were greater in plants produced from the larger seeds.

With many other crops conclusions similar to those of Lehmann have been reached[1], for instance, Lyon and Hitchcock (53) with alfalfa, Walker (76) with beet, Shamel (65) with tobacco, Webber and Boykin (78) with several varieties of cotton, and Sprecher (68) with *Hevea brasiliensis*, but the results recorded by Fruwirth in 1917 are worth recording in more detail. Fruwirth (22) carried out investigations with lucerne and sainfoin for five years. His work proceeded from the earlier investigations of Wollny (81), who showed that for a given area and equal numbers of plants heavy seeds of fodder maize and red clover were superior to the light seeds. Fruwirth's work is excellent in that he eliminated spacing as a factor disturbing the yield results. Three lines of experiment were followed, viz.:

(i) comparison of single plants;

[1] Arthur (1), Zavitz (84), and Cummings (12) give data which clearly show a distinct advantage in the use of large and heavy seed in the case of several different classes of farm crops.

(ii) seed-bed experiments, using equal numbers of plants and also equal weights of seed, the results from which were compared;

(iii) field experiments for comparing yields from heavy and light seed respectively, using equal numbers of plants per given area.

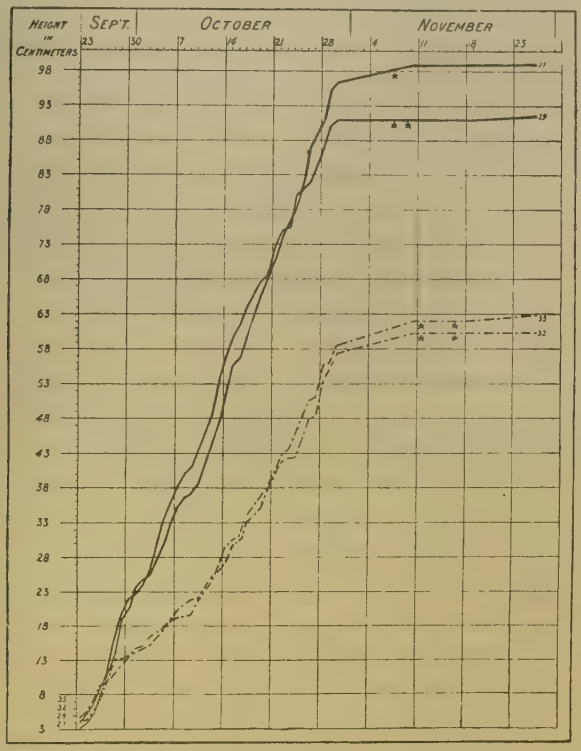

Fig. 2. Curves showing development of Extra Early Alaska Peas from heavy and light seed respectively. The upper curves represent plants from heavy seed and the lower curves plants from light seed. The stars indicate when the pods were ready for the table. (After Hicks and Dabney.)

From each line of investigation similar results followed. For equal numbers of plants per given area the heavier seeds gave rise to plants of greater productivity than that of the plants produced from the lighter seeds. He also found that the superiority of the heavier seed became more marked the larger the ground space ("Standraum") allowed for each plant. The superiority of the plants from the heavier seeds

decreased with the increasing age of the plants, and the author concluded that the result depended upon the larger quantity of reserve materials in the heavier seeds. In the case of perennial plants the original advantage of the heavier seed is gradually lost.

C. Conclusion.

The general conclusion to be drawn from this review of the literature is that the effect of parental conditions upon the seed in determining its subsequent course of development may be considerable.

The environmental conditions operating upon the seed whilst on the parent plant may be divided into two classes, viz.:

(1) The environment of the seed itself, in other words, its position on the parent plant. The effect of the position of the seed upon the parent plant is most clearly reflected in the size of the seed and is independent of external conditions. The balance of evidence is in favour of the conclusion that larger seeds give rise to more vigorous plants and a better yield.

(2) The environment of the parent. Here again differences in the size of the seed are the only effects which are visible in the seed itself, but there is evidence that environmental conditions which affect the parent may also markedly influence the subsequent course of development of the seeds produced. So that effects which become visible in one generation may have to be traced back to the external conditions which operated in a previous generation.

The question of the pre-determining effect of parental conditions is much complicated by the ever-present possibility of hereditary factors being concerned, and in most cases the facts have so far been almost entirely considered from the point of view of heredity alone. In the following sections, in which we shall deal with the pre-determining effect of the conditions operating during harvesting, dormancy (storage), and germination respectively, the difficulty of interpreting the results will not be complicated by the intrusion of the question of heredity.

(*To be continued.*)

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A LIST OF COCCIDAE AFFECTING VARIOUS GENERA OF PLANTS.

By E. ERNEST GREEN, F.E.S., F.Z.S.

(*Continued from Vol. IV, page* 239)

LABURNUM (Leguminosae).
- Phenacoccus aceris.
- Lecanium corni.
- Chionaspis salicis.
- Lepidosaphes ulmi.

LACTUCA (Compositae) 'Lettuce.'
- Orthezia insignis.

LAGERSTROEMIA (Lythraceae).
- Eriococcus lagerstroemiae.

LAMIUM (Labiatae).
- Asterolecanium fimbriatum.

LANDOLPHIA (Apocynaceae).
- Tachardia albizziae.
- Ischnaspis filiformis.

LANTANA (Verbenaceae).
- Orthezia insignis.
- Pseudococcus longispinus.
- Ceroputo yuccae.
- Asterolecanium pustulans-seychellarum.
- Pulvinaria antigoni.
- Hemichionaspis minor.
- Aspidiotus cydoniae.

LAPAGERIA (Liliaceae).
- Aspidiotus hederae.

LAPOANA (Compositae).
- Gueriniella serratulae.

LARREA (Zygophyllaceae).
- Icerya rileyi, rileyi-larreae.
- Gymnococcus lahillei.
- Tachardia larreae.
- Eriococcus larreae.
- Erium irishi, steeli.
- Lecaniodiaspis americana.
- Lecanium elegans.
- Ceroplastes irregularis.
- Aspidiotus larreae.
- Protargionia larreae.

LASIANTHUS (Rubiaceae).
- Lepidosaphes lasianthi.

LATANIA (Palmaceae).
- Pseudococcus nipae.
- Diaspis bromeliae.
- Aspidiotus lataniae, dictyospermi.
- Ischnaspis filiformis.

LATHYRUS (Leguminosae).
- Orthezia urticae.

LAURUS (Lauraceae).
- Icerya braziliensis, purchasi.
- Pseudococcus indicus, laurinus, citrophilus, longispinus.
- Lecanium brunfelsiae, tessellatum, hesperidum, hesperidum-lauri, cerasi, inflatum, elongatum, oleae.
- Paralecanium geometricum.
- Pulvinaria plana, floccifera.
- Protopulvinaria pyriformis.
- Platinglisia noacki.
- Gascardia madagascariensis.
- Aspidiotus cyanophylli, camelliae, ficus, hederae, lauretorum, britannicus, laurina, dictyospermi.
- Cryptaspidiotus aonidioides.
- Xanthophthalma concinnum.
- Aonidia lauri.
- Lepidosaphes nigra.

LAVANDULA (Labiatae) 'Lavender.'
- Pseudococcus lavandulae, citri.

LAVATERA (Malvaceae).
- Lecanium oleae.

LAWSONIA (Lythraceae).
Walkeriana cinerea.
Lecanium nigrum.
LEDUM (Ericaceae).
Pseudococcus ledi.
LEONTODON (Compositae) 'Dandelion.'
Orthezia urticae.
LEPIDIDENIA (Lauraceae).
Lecanium expansum.
LEPIDIUM (Cruciferae).
Macrocerococcus superbus.
LEPIDOSPERMA (Cyperaceae).
Aspidiotus cladii.
LEPTILON (Compositae).
Lecanium hemisphaericum.
LEPTOCARPUS (Restiaceae).
Odonaspis leptocarpi.
LEPTOSPERMUM (Myrtaceae).
Icerya koebelei.
Coelostomidia wairoensis.
Sphaerococcus leptospermi, pirogallis, rugosus.
Asterolecanium epacridis, fimbriatum, stypheliae.
Eriococcus leptospermi.
Ripersia leptospermi.
Tachardia melaleucae.
Ctenochiton flavus.
Inglisia leptospermi, ornata.
Chionaspis eugeniae, angustata.
Poliaspis exocarpi.
Fiorinia fioriniae.
Aspidiotus cladii.
Lepidosaphes intermedia, leptospermi.
LESPEDEZA (Leguminosae).
Icerya genistae.
LEUCADENDRON (Proteaceae).
Pseudococcus trichiliae.
Aspidiotus camelliae.
LEUCOPOGON (Epacridaceae).
Asterolecanium epacridis.
Poliaspis media.
LIBOCEDRUS (Coniferae).
Aspidiotus ehrhorni.
LICHENS.
Phenacoccus kuwanae.
LIGUSTICUM (Umbelliferae).
Ripersia halophila.
LIGUSTRUM (Oleaceae) 'Privet.'
Asterolecanium fimbriatum.
Ericerus pela.
Lecanium hemisphaericum.
Chionaspis salicis.
Leucaspis japonica.
Aspidiotus africanus, dictyospermi, hederae, perniciosus, ficus.
Lepidosaphes ulmi.
LILIACEAE, sundry.
Pseudococcus liliaceum, simplex.
LIMNANTHEMUM (Gentianaceae).
Lecanium limnanthemi.
LIMONIA (Rutaceae).
Aspidiotus orientalis.
Leucaspis limoniae.
LIQUIDAMBAR (Hamamelidaceae).
Aspidiotus juglansregiae-pruni.
Cryptophyllaspis liquidambaris.
LIRIODENDRON (Magnoliaceae) 'Tulip tree.'
Icerya brasiliensis.
Phenacoccus aceris.
Lecanium liriodendri, tulipiferae.
Chionaspis salicis-nigrae.
Aspidiotus piceus.
LITHOSPERMUM (Boragineae).
Asterolecanium fimbriatum.
LITSEA (Lauraceae).
Walkeriana floriger.
Asterolecanium litseae.
Lecanium litseae, acutissimum, expansum, mangiferae, tessellatum.
Chionaspis litseae, pallida.
Lepidosaphes maideni, retrusus.
LIVISTONIA (Palmaceae).
Icerya aegyptiaca.
Pulvinaria psidii.
Fiorinia pellucida.
Aspidiotus britannicus, rapax, ficus, spinosus.
LODOICEA (Palmaceae).
Gymnaspis grandis.
LONICERA (Caprifoliaceae).
Orthezia insignis.
Pseudococcus longispinus.
Phenacoccus aceris.
Lecanium vini, corni, hesperidum.
Protopulvinaria pyriformis.
Aspidiotus perniciosus, palmae, hederae.
Lepidosaphes ulmi.

LORANTHUS (Loranthaceae).
Porococcus pergandei, tinctorius.
Erioides rimulae.
Lecanium hemisphaericum, viride, nigrum.
Pulvinaria betulae.
Protopulvinaria longivalvata.
Tectopulvinaria loranthi.
Inglisia foraminifer.
Diaspis phoradendri, visci, loranthi, pentagona-rubra, barberi, parva.
Chionaspis fodiens, vitis, salicis, nilgirica, varicosa.
Hemichionaspis mussoendae.
Fiorinia rubrolineata.
Aspidiotus destructor, transparens, pothi, fuscus, fodiens.
Hybridaspis producta.
Aonidia loranthi, obscura.
Lepidosaphes kamerunensis.
LOTUS (Leguminosae).
Asterolecanium fimbriatum.
Macrocerococcus superbus.
Pseudococcus longispinus.
LUZULA (Gramineae).
Newsteadia floccosa.
Eriopeltis festucae.
Luzulaspis luzulae.
LYCASTE (Orchidaceae).
Pulvinaria floccifera.
LYCIUM (Solanaceae).
Tachardia lycii.
Lecanium hesperidum.
Pulvinaria argentina.
Lichtensia lycii.
Ceroplastes jamaicensis.
Lepidosaphes ulmi.
LYCOPERSICUM (Solanaceae) 'Tomato.'
Orthezia insignis.
Pseudococcus solani, virgatus, maritimus.
Phenacoccus solani.
Chionaspis solani.
LYONIA (Ericaceae).
Chionaspis salicis.
MACARANGA (Euphorbiaceae).
Lecanium formicarii.
Chionaspis pellucida.
MACHILUS (Lauraceae).
Fiorinia phantasma.
Parlatoria proteus.
Lepidosaphes machili.
MACLURA (Moraceae) 'Osage Orange.'
Lecanium aurantiacum, maclurarum, robiniae.
Pulvinaria maclurae.
Aspidiotus ancylus, perniciosus.
MACROLOBIUM (Leguminosae).
Diaspis hamata.
Chionaspis bussii.
Lepidosaphes meridionalis.
MACROZAMIA (Cycadaceae).
Pseudococcus macrozamiae.
Paralecanium frenchi-macrozamiae.
Aspidiotus hederae.
Parlatoria proteus.
MAGNOLIA (Magnoliaceae).
Pseudococcus maritimus.
Lecanium turgidum, magnoliarum, tulipiferae, oleae, nigrofasciatum.
Ceroplastes rubens.
Leucaspis japonica.
Pseudoparlatoria parlatorioides.
Aspidiotus hederae, persearum, perseae, dictyospermi.
Lepidosaphes gloveri.
Ischnaspis filiformis.
MALLOTUS (Euphorbiaceae).
Chionaspis malloti.
MALVA (Malvaceae).
Pseudococcus capensis.
Phenacoccus solani.
MALVACEAE, miscellaneous.
Pseudococcus capensis.
Phenacoccus gossypii, iceryoides.
Pulvinaria cestri, tuberculatus.
Inglisia malvacearum.
MALVASTRUM (Malvaceae).
Eriococcus tinsleyi.
MALVAVISCUS (Malvaceae).
Ceroplastes dugesii.
Aspidiotus tesseratus.
MAMMEA (Guttiferae).
Pulvinaria mammeae.
Diaspis pentagona.
Howardia biclavis.
Aspidiotus lucumae, destructor, personatus.
MAMMILLARIA (Cactaceae).
Pseudococcus mammillariae.
Rhizoecus targionii.

MANGIFERA (Anacardiaceae) 'Mango.'
- Monophlebus stebbingi-mangiferae, octocaudata.
- Llaveia axin.
- Icerya seychellarum, minor.
- Asterolecanium pustulans.
- Pseudococcus longispinus, obtusus, marchali, virgatus.
- Phenacoccus mangiferae, iceryoides, ballardi.
- Lecanium acuminatum, mangiferae, psidii, adersi, acutissimum, punctuliferum, diversipes, discrepans.
- Pulvinaria psidii, ficus.
- Ceroplastes ceriferus, floridensis, rubens, actiniformis.
- Vinsonia stellifera.
- Diaspis rosae, cinnamomi-mangiferae, tubercularis, pentagona, barberi.
- Chionaspis dilatata, natalensis, vitis, hedyotidis.
- Hemichionaspis aspidistrae.
- Leucaspis indica.
- Aspidiotus destructor, trilobitiformis-darutyi, dictyospermi, personatus, greeni, rossi, biformis, aurantii.
- Pseudischnaspis linearis.
- Parlatoria calianthina.

MANIHOT (Euphorbiaceae) 'Tapioca,' 'Ceara Rubber,' etc.
- Llaveia primitiva.
- Stigmacoccus zimmermanni.
- Lecaniodiaspis manihotis.
- Lecanium nigrum.
- Pseudococcus virgatus.
- Diaspis pentagona.
- Hemichionaspis aspidistrae.
- Fiorinia fioriniae.
- Aspidiotus cyanophylli, destructor.
- Lepidosaphes dispar.

MARANTA (Zingiberaceae).
- Lecanium hesperidum, nigrum.
- Aspidiotus ficus.

MARISCUS (Cyperaceae).
- Chionaspis paolii.

MARKHAMIA (Bignoniaceae).
- Stictococcus dimorphus.
- Lecanium somereni.
- Pulvinaria psidii.

MATAYBA (Sapindaceae).
- Aspidiotus tesseratus.

MATRICARIA (Compositae).
- Orthezia urticae.

MAYTENUS (Celastraceae).
- Lecanium mayteni, obscurum.
- Ceroplastes albolineatus, communis, formicarius, rotundus, sanguineus.

MEDICAGO (Leguminosae).
- Gueriniella serratulae.
- Asterolecanium fimbriatum.

MELALEUCA (Myrtaceae).
- Tessarobolus guerinii.
- Ascelis melaleucae.
- Sphaerococcus acaciae-melaleucae, ferrugineus, morrisoni, tepperi, pulchellus.
- Tachardia melaleucae.
- Lecaniodiaspis melaleucae.
- Eriococcus imperfectus.
- Lecanium melaleucae, hemisphaericum.
- Ceroplastes ceriferus.
- Ceroplastodes melaleucae.
- Ctenochiton cellulosus.
- Chionaspis eugeniae.
- Fiorinia expansa.
- Aspidiotus casuarinae, fodiens, unilobis, dictyospermi, delicatulus, tuberculatus.
- Lepidosaphes melaleucae, nivea, spinosa, crassa, incisor.

MELAMPYRUM (Scrophulariaceae).
- Orthezia urticae.
- Margarodes polonicus.

MELASTOMA (Melastomaceae).
- Aspidiotus transparens.

MELIA (Meliaceae).
- Lecanium nigrofasciatum, nigrum, hemisphaericum.
- Pulvinaria maxima.
- Diaspis crawi-fulleri.
- Hemichionaspis minor.
- Aspidiotus hederae, orientalis.

MELICOPA (Rutaceae).
- Eriochiton spinosus.

MELICYTUS (Violaceae).
- Chionaspis dysoxyli.

MELITTIS (Labiatae).
- Orthezia urticae.

MELOCHIA (Sterculiaceae).
Pseudococcus corymbatus.
MEMECYLON (Melastomaceae).
Lecanium bicruciatum, caudatum, fusiforme, hemisphaericum.
Aonidia crenulata.
MENISPERMUM (Menispermaceae).
Lecanium cecconi, corni, persicae.
MESEMBRYANTHEMUM (Aizoaceae).
Pseudococcus capensis.
Pulvinaria mesembryanthemi.
Parafairmairia bipartita.
Aspidiotus lounsburyi, hederae.
MESPILUS (Rosaceae) 'Medlar,' etc.
Phenacoccus mespili, aceris.
Lecanium bituberculatum, corni, coryli.
Pulvinaria carpini, betulae.
Ceroplastes rusci.
Epidiaspis lepèrei.
Aspidiotus hederae, ostreaeformis, piri.
Parlatoria oleae.
Lepidosaphes ulmi.
MESUA (Guttiferae).
Amorphococcus mesuae.
Aonidia mesuae, ferreae, perplexa.
Aspidiotus cuculus.
Parlatoria mesuae.
Gymnaspis spinomarginata.
Lepidosaphes ambigua.
METROSIDEROS (Myrtaceae).
Eriococcus pallidus.
Lecanium hesperidum.
Lecanochiton metrosideri, minor.
Aspidiotus dictyospermi.
Lepidosaphes metrosideri.
METROXYLON (Palmaceae) 'Sago Palm.'
Lecanium hemisphaericum.
MICHELIA (Magnoliaceae).
Lecanium punctuliferum.
Aspidiotus maskelli, camelliae.
Parlatoria champaca.
MICONIA (Melastomaceae).
Pulvinaria depressa.
Ceroplastes purpureus.
MICROGLOSSA (Compositae).
Howardia biclavis.
MICROGYNE (Compositae).
Diaspis pugionifera.
Aspidiotus replicatus.
MICROLOBIUM (Leguminosae).
Lecanium quinquepori.
MICROMERIA (Labiatae).
Lecanium hesperidum.
Chionaspis canariensis, berlesii.
MILIUM (Gramineae).
Antonina purpurea.
Aclerda subterranea.
MILIUSA (Anonaceae).
Aonidia targioniopsis.
MIMOSA (Leguminosae).
Lophococcus mirabilis.
Palaeococcus hempeli.
Icerya littoralis-mimosae.
Cryptokermes brasiliensis.
Lecaniodiaspis mimosae.
Pseudococcus longispinus.
Tachardia albida, fulgens, lacca,
Lecanium hesperidum. [mexicana.
Lichtensia mimosae, parvula.
Ceroplastes confluens, egbarum, mimosae.
Ceroplastodes dugesii.
Schizochlamidia mexicana.
Diaspis pentagona.
Aspidiotus mimosae, phenax, denti-
Lepidosaphes mimosarum. [lobis.
MIMULUS (Scrophulariaceae).
Ceroputo yuccae.
MIMUSOPS (Sapotaceae).
Lecanium expansum, scutatum.
Aspidiotus malleolus, trilobitiformis, dictyospermi.
Aonidia spinosissima.
MISCANTHUS (Gramineae).
Ripersia japonica, agasawarensis.
Lepidosaphes arii.
MISCHOCARPUS (Sapindaceae).
Chionaspis mischocarpi.
MOESA (Myrsineae).
Lecanium tessellatum.
Hemichionaspis mussoendae.
Aspidiotus transparens.
Lepidosaphes cocculi.
MOLINIA (Gramineae).
Pseudococcus perrisi.
MONANTHERA (Crassulaceae).
Chionaspis berlesii.
MONARDELLA (Labiatae).
Phenacoccus stachyos.

MONODORA (Anonaceae).
- Icerya seychellarum.
- Lecanium longulum.

MONOTOCA (Epacridaceae).
- Tachardia decorella.

MONSTERA (Araceae).
- Lecanium longulum, melaleucae.
- Ischnaspis filiformis.

MORINDA (Rubiaceae).
- Pulvinaria psidii.
- Chionaspis thoracica.
- Aspidiotus orientalis.

MORINGA (Moringeae).
- Howardia biclavis.

MORUS (Moraceae) 'Mulberry.'
- Monophlebus octocaudatus.
- Gueriniella serratulae.
- Icerya longisetosa, purchasi.
- Asterolecanium pustulans.
- Pseudococcus bromeliae, comstocki, citri, filamentosus, virgatus, longispinus, longicornis.
- Stictococcus dimorphus, diversiseta.
- Lecanium hesperidum, mori, ribis, websteri, nishigaharae, oleae, somereni, nigrofasciatum, corni, persicae.
- Pulvinaria innumerabilis, kuwacola, maxima, cupaniae, psidii.
- Takahashia japonica.
- Ceroplastes rusci, ceriferus, solidus.
- Inglisia bivalvata.
- Diaspis pentagona.
- Aspidiotus aurantii, mori, longispinus, lataniae, hederae, perniciosus.

MOSSES.
- Orthezia cataphracta.
- Newsteadia floccosa.
- Ortheziola vejdovskyi.
- Pseudococcus sphagni.
- Ripersia globata.

MUEHLENBECKIA (Polygonaceae).
- Coelostomidia zealandica.
- Lecanium hesperidum.
- Pulvinaria psidii.
- Eriochiton spinosus.
- Inglisia foraminifera, fossilis.
- Ceroplastes sinensis.
- Aspidiotus dictyospermi, lataniae, hederae, cyanophylli.

MURALTIA (Polygalaceae).
- Pseudococcus muraltiae.

MURRAYA (Rutaceae).
- Phenacoccus iceryoides.
- Lecanium discrepans.
- Aspidiotus trilobitiformis-darutyi, quadriclavatus.
- Fiorinia rubrolineata.
- Lepidosaphes citricola.

MUSA (Musaceae).
- Icerya montserratensis.
- Pseudococcus citri, longispinus, bromeliae, nipae.
- Ceroputo yuccae.
- Lecanium signiferum, hesperidum, hemisphaericum, discrepans.
- Protopulvinaria pyriformis.
- Hemichionaspis minor.
- Aspidiotus destructor, palmae, ficus, personatus, orientalis, excisus, lataniae, cyanophylli, scutiformis, hederae, articulatus, cydoniae.

MUSSOENDA (Rubiaceae).
- Lecanium nigrum.
- Hemichionaspis mussoendae.

MYOPORUM (Myoporaceae).
- Eriococcus pallidus, eucalypti.
- Pseudococcus stolatus.
- Lecanium hemisphaericum.
- Pulvinaria dodoneae, greeni.
- Ctenochiton testudo.
- Aspidiotus camelliae, myopori.
- Leucaspis myopori.

MYRCEUGENIA (Myrtaceae).
- Lepidosaphes diaspidiformis.

MYRCIA (Myrtaceae).
- Pseudischnaspis linearis.

MYRCIARIA (Myrtaceae).
- Cepulinia jaboticabae.

MYRICA (Myricaceae).
- Tachardia decorella.
- Phenacoccus aceris.
- Lecanium longulum, capreae.
- Ceroplastes ceriferus, myricae.
- Aspidiotus duplex.
- Lepidosaphes ulmi.

MYRISTICA (Myristicaceae) 'Nutmeg.'
- Lecaniodiaspis malaboda.
- Lecanium mangiferae, incisum, psidii.
- Paralecanium expansum, expan-

MYRISTICA (Myristicaceae)—*cont.*
sum-metallicum, expansum-quadratum.
VINSONIA stellifera.
DIASPIS myristicae.
CHIONASPIS dilatata.
ASPIDIOTUS destructor, samoana.
AONIDIA javanensis.
ISCHNASPIS filiformis.
MYRSINE (Myrsinaceae).
ASPIDIOTUS hederae, lauretorum.
MYRTACEAE, miscellaneous.
APIOCOCCUS asperatus, globosus, gregarius, singularis.
TECTOCOCCUS ovatus.
SPHAEROCOCCUS socialis.
PSEUDOCOCCUS grandis.
ERIOCOCCUS perplexus.
TACHARDIA parva.
LECANIUM discoides, glanulosa, reticulata, inflatum.
PULVINARIA grandis, psidii.
CEROPLASTES janeirensis, simplex, speciosus, variegatus.
PLATINGLISIA noacki.
DIASPIS australis.
DIASPIDISTIS multilobis.
ASPIDIOTUS trilobitiformis.
MYRTUS (Myrtaceae).
CEROPLASTES cirripediformis, floridensis, rusci.
LECANIUM nitens, hesperidum, oleae, myrti.
PULVINARIA psidii.
FILIPPIA oleae.
DIASPIS rosae.
CHIONASPIS myrthi.
PSEUDOPARLATORIA serrulata.
ASPIDIOTUS ficus, dictyospermi, rapax.
PARLATORIA myrtus, proteus, proteus-virescens.
LEPIDOSAPHES myrthi.

NAPOLEONA (Lecithydaceae).
STICTOCOCCUS sjostedti.
NARDUS (Gramineae).
RIPERSIA subterranea.
LUZULASPIS luzulae.
NECTANDRA (Lauraceae).
ASPIDIOTUS tesseratus, cydoniae.
PSEUDOPARLATORIA noacki.

NEGUNDO (Aceraceae).
PULVINARIA innumerabilis.
NEOLITSEA (Lauraceae).
FIORINIA phantasma.
NEPHELIUM (Sapindaceae).
TACHARDIA albizziae.
LECANIUM acutissimum, nigrum.
PULVINARIA psidii.
DIASPIS euphoriae.
FIORINIA nephelii, hirsuta.
ASPIDIOTUS trilobitiformis.
NEPHRODIUM (Filices).
PSEUDOCOCCUS longispinus.
LEPIDOSAPHES desmidioides.
NEPHROLEPIS (Filices).
LECANIUM mori, hesperidum.
NERIUM (Apocynaceae) 'Oleander.'
ASTEROLECANIUM pustulans.
PSEUDOCOCCUS burnerae, citri, virgatus.
LECANIUM hesperidum, hemisphaericum, oleae, nigrofasciatum, persicae.
CEROPLASTES nerii, floridensis, townsendi, percrassus.
DIASPIS pentagona.
CHIONASPIS nerii.
HEMICHIONASPIS minor.
ASPIDIOTUS hederae, ficus, rossi, trilobitiformis, dictyospermi, cydoniae.
AONIDIA distinctissima.
PARLATORIA pergandei, oleae, calianthina.
NICOTIANA (Solanaceae) 'Tobacco.'
PSEUDOCOCCUS nicotianae.
LECANIUM nicotianae.
PULVINARIA floccifera.
NIPA (Palmaceae).
PSEUDOCOCCUS nipae.
NITRARIA (Zygophyllaceae).
ASPIDIOTUS nitrariae.
NOTHOFAGUS (Corylaceae).
FAGISUGA triloba.
NOTHOPANAX (Araliaceae).
LEUCASPIS gigas.
NOTHOPEGIA (Anacardiaceae).
LECANIUM bicruciatum.
ASPIDIOTUS rossi, trilobitiformis.
PARLATORIA blanchardi, aonidiformis.
GYMNASPIS bullata.

NUYTSIA (Loranthaceae).
PULVINARIA maskelli-nuytsiae.
NYSSA (Cornaceae).
CHIONASPIS nyssae, sylvatica.

OCHNA (Ochnaceae).
LECANIUM tessellatum.
HOWARDIA biclavis.
OCIMUM (Labiatae).
CEROPLASTODES cajani.
OCOTEA (Lauraceae).
ASPIDIOTUS lauretorum, laurinus.
FIORINIA pellucida.
ODINA (Mangiferae).
PHENACOCCUS iceryoides.
FIORINIA odinae.
ODONTOGLOSSUM (Orchidaceae).
ASPIDIOTUS odontoglossi.
OLEA (Oleaceae) 'Olive.'
GUERINIELLA serratulae.
ICERYA purchasi.
POLLINIA pollini.
PSEUDOCOCCUS citri.
PHENACOCCUS oleae, eleabius, farnerianae.
LECANIUM nigrofasciatum, oleae, hesperidum.
LICHTENSIA eatoni.
FILIPPIA oleae, chrysophyllae.
EUPHILIPPIA olivina.
DIASPIS bromeliae, oleae.
EPIDIASPIS lepèrei.
CHIONASPIS nerii, olivina, ceratoniae.
LEUCASPIS epidaurica, riccae.
ASPIDIOTUS hederae, osmanthi, camelliae, aurantii, duplex, rossi, oppugnatus, opimus, articulatus, tafirenus, britannicus, dictyospermi, lenticularis.
PARLATORIA affinis, calianthina, oleae.
LEPIDOSAPHES flava, beckii-oleae, gloveri, pinnaeformis.
OLEARIA (Compositae).
CRYPTORHIZOCOCCUS olearíae.
ERIOCHITON hispidus.
ASPIDIOTUS hederae.
ONAGRA (Onagraceae).
LECANIUM corni.
ONCIDIUM (Orchidaceae).
ASTEROLECANIUM aureum, epidendri.
PULVINARIA camelicola, floccifera.
PSEUDOPARLATORIA parlatorioides.
ONCOBA (Bixaceae).
LEUCASPIS cockerelli.
ONOBRYCHIS (Leguminosae).
ORTHEZIA urticae.
ONONIS (Leguminosae).
DIASPIS pentagona.
ASPIDIOTUS hederae.
OPHIOPOGON (Haemodoraceae).
ASTEROLECANIUM aureum.
PARLATORIA proteus.
OPHIORRHIZA (Rubiaceae).
LECANIUM ophiorrhizae.
PULVINARIA tessellata.
OPHRYOSPORUS (Compositae).
ASPIDIOTUS argentinus.
OPUNTIA (Cactaceae) 'Prickly Pear.'
GUERINIELLA serratulae.
DACTYLOPIUS cacti, confusus, confusus-newsteadi, tomentosus, capensis, argentinus, ceylonicus.
PSEUDOCOCCUS obscurus.
DIASPIS echinocacti.
ORCHIDACEAE 'Orchids.'
CONCHASPIS angraeci.
ASTEROLECANIUM aureum, epidendri.
LECANIODIASPIS dendrobii.
LECANIUM acuminatum, anthurii, hemisphaericum, pseudohesperidum, tessellatum.
DIASPIS boisduvallii, cattleyae, alienus.
HEMICHIONASPIS aspidistrae, minor.
FIORINIA fioriniae.
LEUCASPIS stricta.
PSEUDOPARLATORIA parlatorioides.
ASPIDIOTUS cyanophylli, hederae, biformis, dictyospermi, odontoglossi, biformis-cattleyae, portoricensis, aurantii, perseae, rossi, transparens.
PARLATORIA proteus, pergandei, pseudaspidiotus.
LEPIDOSAPHES pinnaeformis, cocculi, vandae, tuberculata.
OREODAPHNE (Lauraceae).
ASPIDIOTUS lauretorum.
OREODOXA (Palmaceae).
ASPIDIOTUS oreodoxae.
ORIXA (Celastraceae).
DIASPIS pentagona-rubra.

ORMOSIA (Leguminosae).
CEROPLASTES vuilleti.
OROBANCHA (Orobanchaceae).
PSEUDOCOCCUS longisetosus.
ORYZA (Gramineae) 'Rice.'
RIPERSIA oryzae.
CHIONASPIS decurvata.
OSBECKIA (Melastomaceae).
ASPIDIOTUS orientalis, camelliae, transparens.
OSMANTHUS (Oleaceae).
PHENACOCCUS suwakoensis.
DIASPIS pentagona-auranticolor.
CHIONASPIS citri.
ASPIDIOTUS britannicus, hederae.
LEPIDOSAPHES uniloba.
OSTODES (Euphorbiaceae).
AONIDIA cornigera.
FIORINIA theae.
OSTRYA (Betulaceae).
PHENACOCCUS aceris.
LECANIUM quercitronis, ribis, websteri.
PULVINARIA betulae.
ASPIDIOTUS osborni, ostreaeformis.
OSYRIS (Santalaceae).
ASTEROLECANIUM fimbriatum.
LECANIUM oleae, persicae.
ASPIDIOTUS hederae, cecconii, trabuti.
OUGEINIA (Leguminosae).
TACHARDIA lacca.
OXALIS (Geraniaceae).
PSEUDOCOCCUS capensis.
OXYLOBIUM (Leguminosae).
POLIASPIS exocarpi.
OXYTENANTHERA (Gramineae).
ASTEROLECANIUM ceriferum-prominens.

PACHIRA (Malvaceae).
LECANIUM chelonioides.
PADUS (Rosaceae).
LECANIUM nigrofasciatum.
POEONIA (Ranunculaceae).
PSEUDOCOCCUS citri.
CHIONASPIS salicis.
LEUCASPIS japonica.
ASPIDIOTUS poeoniae.
PALMACEAE 'Palms.'
ICERYA montserratensis, seychellarum.
HALIMOCOCCUS lampas, borassi.
PHOENICOCOCCUS marlatti.
ASTEROLECANIUM palmae, urichi, spectabile.
PSEUDOCOCCUS arecae, nipae, cocotis, pseudonipae, virgatus, citri, longispinus.
RIPERSIA palmarum.
LECANIUM tessellatum, acutissimum, longulum, minimum, palmae, hemisphaericum, oleae, hesperidum.
CEROPLASTES actiniformis, rubens.
VINSONIA stellifera.
DIASPIS boisduvallii, boisduvallii-coccois, pentagona.
CHIONASPIS citri, cockerelli, eugeniae, substriata, unilateralis, dentilobis, dilatata, inday, pseudonivea.
HEMICHIONASPIS aspidistrae, minor, marchali.
PINNASPIS buxi.
POLIASPIS cycadis.
LEUCASPIS cockerelli.
FIORINIA fioriniae, kewensis, macroprocta, pellucida.
ASPIDIOTUS cyanophylli, lataniae, destructor, simillimus, ficus, rossi, dictyospermi, personatus, spinosus, chamaeropsis, cydoniae, aurantii, perseae, oceanica, ostreaeformis, oreodoxae, pseudospinosus, cocotiphagus, elaeidis, propsimus, articulatus, orientalis, coryphae, palmae, fissidens-constricta, hederae, rapax, mauritianus, pangoensis.
COMSTOCKIELLA sabalis, sabalis-mexicana.
GYMNASPIS grandis.
PARLATORIA blanchardi, proteus, ziziphus, greeni, mangiferae.
LEPIDOSAPHES gloveri, mcgregori, unicolor.
ISCHNASPIS filiformis.
PANAX (Araliaceae).
PSEUDOCOCCUS glaucus.
CTENOCHITON flavus, fuscus, perforatus, viridis.
FIORINIA minima.
PANCRATIUM (Amaryllidaceae).
PSEUDOCOCCUS simplex.

PANDANUS (Pandanaceae) 'Screw-pines.'
- Pseudococcus pandani, longispinus.
- Tylococcus giffardi.
- Lecanium pseudexpansum.
- Ceroplastes actiniformis.
- Chionaspis dilatata, pseudaspidistrae.
- Hemichionaspis aspidistrae.
- Pinnaspis buxi.
- Aspidiotus pandani, dictyospermi, aurantii, ficus.
- Porogymnaspis rufa, angulata.
- Ischnaspis filiformis.
- Lepidosaphes greeni.

PANICUM (Gramineae).
- Lecanium hemisphaericum.
- Diaspis uncinati.
- Aspidiotus marlatti, panici, sacchari.

PARIETARIA (Urticaceae).
- Pseudococcus parietariae.
- Orthezia urticae.

PARINARIUM (Chrysobalanaceae).
- Aspidiotus fissidens.

PARITIUM (Malvaceae).
- Diaspis pentagona.

PARKINSONIA (Leguminosae).
- Inglisia chelonioides.
- Aspidiotus parkinsoniae.

PARSONSIA (Apocynaceae).
- Hemichionaspis minor.

PARTHENIUM (Compositae).
- Lecaniodiaspis yuccae.
- Tachardia cornuta.

PASANIA (Fagaceae).
- Asterolecanium pasaniae, tokyonis.
- Pseudococcus quercicola.
- Aspidiotus densiflorae.

PASSIFLORA (Passifloraceae).
- Pseudococcus burnerae, longispinus,
- Lecanium caudatum. [maritimus.
- Pulvinaria jacksoni.
- Aspidiotus hederae, trilobitiformis.

PATERSONIA (Iridaceae).
- Lecanium patersoniae.

PAULOWNIA (Scrophulariaceae).
- Diaspis pentagona.

PAVETTA (Rubiaceae).
- Lecanium caudatum.

'PEACH' (Amygdalus persica).
- Astrolecanium pustulans.
- Pseudococcus capensis.
- Phenacoccus aceris.
- Lecanium armeniacum, canadense, cerasifex, cockerelli, persicae, pruinosum, prunastri, rugosum, hemisphaericum, persimile, nigrofasciatum, hesperidum.
- Pulvinaria amygdali.
- Ceroplastes rusci.
- Diaspis lepèrii, pentagona, squamosa.
- Epidiaspis piricola.
- Pseudoparlatoria parlatorioides.
- Chionaspis furfura.
- Aspidiotus ancylus, forbesi, juglansregiae, ostreaeformis, lataniae, perniciosus, cyanophylli.
- Parlatoria calianthina.

PEDDIEA (Thymeliaceae).
- Aspidiotus trilobitiformis.

PELARGONIUM (Geraniaceae).
- Icerya purchasi.
- Asterolecanium fimbriatum.
- Pseudococcus capensis.
- Pulvinaria psidii.
- Diaspis pentagona.
- Hemichionaspis minor.

PELLAEA (Filices).
- Chionaspis dubia.

PENTACME (Dipterocarpaceae).
- Tachardia lacca.

PERGULARIA (Asclepiadaceae).
- Lecanium caudatum.

PERSEA (Lauraceae) 'Avocado Pear.'
- Icerya montserratensis, seychellarum.
- Pseudococcus citri, longispinus, nipae.
- Ceroplastes cistudiformis, floridensis, rubens.
- Lecanium hemisphaericum.
- Protopulvinaria pyriformis.
- Diaspis pentagona.
- Pinnaspis rhombica.
- Fiorinia fioriniae.
- Aspidiotus persearum, perseae, scutiformis, destructor, hederae, dictyospermi, lauretorum, subsimilis, personatus, palmae, maskelli.
- Pseudoparlatoria parlatorioides, ostreata.
- Lepidosaphes longula, mimosarum.

PERSONIA (Proteaceae).
CHIONASPIS eugeniae.
PETROPHILA (Proteaceae).
ASTEROLECANIUM petrophilae.
PARLATORIA petrophilae.
PETROPHYES (Crassulaceae).
CHIONASPIS berlesii.
PHAGNALON (Compositae).
ASTEROLECANIUM fimbriatum.
PHAJUS (Orchidaceae).
PULVINARIA floccifera.
PHALERIA (Thymeliaceae).
TACHARDIA aurantiaca.
PHASEOLUS (Leguminosae) 'Garden Beans,' etc.
PSEUDOCOCCUS virgatus.
PULVINARIA antigoni.
DIASPIS pentagona.
ASPIDIOTUS articulatus.
PHILADELPHUS (Saxifragaceae).
LECANIUM corni.
PHILLYREA (Oleaceae).
LECANIUM oleae.
LICHTENSIA catoni.
FILIPPIA oleae.
ASPIDIOTUS hederae.
LEPIDOSAPHES conchiformis.
PHILODENDRON (Araceae).
PSEUDOCOCCUS nipae.
LECANIUM insolens.
PULVINARIA idesiae.
PINNASPIS buxi.
PHLEUM (Gramineae).
PSEUDOCOCCUS elongatus.
PHENACOCCUS graminis.
PHLOMIS (Labiatae).
ORTHEZIA urticae.
PHLOX (Polemoniaceae).
LECANIUM hesperidum.
PHOEBE (Lauraceae).
ASPIDIOTUS barbusano.
PHOENIX (Palmaceae) 'Date Palms.'
ICERYA aegyptiaca.
PHOENICOCOCCUS marlatti.
SPHAEROCOCCUS draperi, marlatti.
PSEUDOCOCCUS nipae.
LECANIUM hesperidum, tessellatum, oleae, expansum.
PHORADENDRON (Loranthaceae).
PSEUDOCOCCUS phoradendri.
LECANIUM phoradendri, nigrofasciatum.
PHORMIUM (Liliaceae) 'New Zealand Flax.'
COELOSTOMIDIA wairoensis.
PSEUDOCOCCUS calceolariae.
LEUCASPIS stricta.
POLIASPIS media.
FIORINIA fioriniae.
ASPIDIOTUS phormii, sphaerioides, dictyospermi, hederae.
LEPIDOSAPHES cordylinidis.
PHOTINIA (Rosaceae).
PULVINARIA photiniae.
ASPIDIOTUS perniciosus-andromelas.
PHRAGMITES (Gramineae).
ANTONINA phragmitis.
ACLERDA biwakoensis.
PHYLLANTHUS (Euphorbiaceae).
ERIOIDES rimulae.
ASPIDIOTUS taprobanus, phyllanthi, lataniae.
PARLATORIA phyllanthi.
PHYLLIREA (Oleaceae).
LEPIDOSAPHES destefanii.
PHYLLOCLADUS (Coniferae).
COELOSTOMIDIA assimilis.
ERIOCOCCUS phyllocladi.
PERRISIA phyllocladi.
PHYLLODIUM (Leguminosae).
CRYPTHEMICHIONASPIS nigra.
PHYLLOSTACHYS (Gramineae).
CHIONASPIS hikosani.
PHYMATODES (Filices).
LEPIDOSAPHES phymatodidis.
PHYTOLACCA (Phytolaccaceae).
PSEUDOCOCCUS capensis.
PICCONIA (Oleaceae).
ASPIDIOTUS lauretorum, hederae.
PICEA (Coniferae).
PHENACOCCUS minimus, piceae.
LECANIUM cooleyi, piceae.
ASPIDIOTUS abietis.
SYNGENASPIS parlatoriae.
PICRADENIA (Compositae).
PALAEOCOCCUS townsendi.
PICRIS (Compositae).
GUERINIELLA serratulae.
PILEA (Urticaceae).
LECANIUM flaveolum.
PIMENTA (Myrtaceae).
LLAVEIA primitiva-pimentae.
PIMPINELLA (Umbelliferae).
ASTEROLECANIUM fimbriatum.

PINUS (Coniferae).
- Monophlebus burmeisteri, maskelli, fuscipennis, hirtus.
- Gueriniella serratulae.
- Icerya purchasi.
- Pseudococcus caricus, pini, comstocki, maritimus.
- Phenacoccus minimus, hystrix.
- Puto antennatus, cupressi.
- Physokermes coloradensis, insignicola, piceae.
- Lecanium genistae, minimum-pinicola, parvicorne, pini.
- Pseudophilippia quaintancei.
- Ceroplastes rubens-minor.
- Diaspis visci.
- Chionaspis pinifoliae, austriaca.
- Poliaspis pini.
- Leucaspis loewi, pini, pusilla, signoreti, perezi, sulcii, corsa, leonardi, affinis, indiae-orientalis, candida.
- Aspidiotus abietis, coniferarum, glanduliferus, californicus, florenciae, corticis-pini, ehrhorni.
- Aonidia pinicola, lauri.
- Parlatoria proteus.
- Lepidosaphes pyriformis, newsteadi, ulmi.

PIPER (Piperaceae) 'Pepper,' etc.
- Pseudococcus glaucus.
- Lecanium piperis, marsupiale, longulum, acutissimum, peradeniyense.
- Protopulvinaria longivalvata.
- Platylecanium cribrigerum.
- Ctenochiton piperis.
- Chionaspis varicosa.
- Hemichionaspis aspidistrae, minor.
- Pinnaspis siphonodontis.
- Fiorinia diaspiformis, proboscidaria.
- Aspidiotus capsulatus, destructor.
- Lepidosaphes piperis, citricola, gloveri.

PIPTURUS (Urticaceae).
- Nesococcus pipturi.

PISONIA (Nyctagineae).
- Pulvinaria pseudofloccifera.

PISTACIA (Anacardiaceae).
- Lecanium oleae.
- Pulvinaria psidii.
- Filippia oleae.
- Ceroplastes rusci.
- Diaspis gennadii, syriaca.
- Leucaspis pistaceae.
- Aspidiotus aurantii, hederae.
- Lepidosaphes pistaceae.

PITCAIRNIA (Bromeliaceae).
- Diaspis boisduvallii.

PITHECOLOBIUM (Leguminosae).
- Icerya montserratensis.
- Tachardia lacca.
- Pseudococcus crotonis.
- Ceronema koebelei.
- Ceroplastes egbarum.
- Inglisia chelonioides.
- Hemichionaspis minor.
- Aspidiotus fodiens.

PITTOSPORUM (Pittosporaceae).
- Icerya purchasi.
- Asterolecanium fimbriatum.
- Cerococcus punctiferus.
- Eriococcus paradoxus, eucalypti.
- Pseudococcus glaucus, longispinus.
- Lecanium notatum, hemisphaericum.
- Pulvinaria psidii, floccifera.
- Ctenochiton perforatus.
- Leucaspis gigas.
- Aspidiotus subrubescens, junctilobius, aurantii, hederae, ficus.
- Parlatoria pittospori, viridis, proteus.
- Lepidosaphes pyriformis, subarmatus.

PITURANTHOS (Umbelliferae).
- Chionaspis bilobis.

PLAGIANTHUS (Malvaceae).
- Ctenochiton depressus.

PLATANUS (Platanaceae) 'Plane tree.'
- Phenacoccus osborni, platani, aceris.
- Lecanium nigrofasciatum, corni.
- Aspidiotus ostreaeformis.

PLATYLOBIUM (Leguminosae).
- Aspidiotus hederae.

PLECTRONIA (Rubiaceae).
- Lecanium luzonicum.
- Hemilecanium recurvatum.

PLOCAMA (Rubiaceae).
- Chionaspis canariensis, berlesii.

PLUCHEA (Compositae).
- Palaeococcus plucheae.
- Lecanium hesperidum.
- Pulvinaria plucheae.

PLUMBAGO (Plumbaginaceae).
ICERYA purchasi.
CEROPLASTES plumbaginis.
PLUMERIA (Apocynaceae).
CONCHASPIS newsteadi.
LECANIUM viride.
PULVINARIA psidii.
HOWARDIA biclavis.
POA (Gramineae).
MARGARODES hamelii.
PHENACOCCUS graminis.
HETEROCOCCUS arenae.
PODOCARPUS (Coniferae).
ICERYA seychellarum.
COELOSTOMIDIA compressa, pilosa.
PHENACOLEACHIA zealandica.
ERIOCOCCUS spinifrons.
RHIZOCOCCUS totarae.
PULVINARIA floccifera.
POLIASPIS pini.
AONIDIA longa.
LEPIDOSAPHES pallida.
POINCIANA (Leguminosae).
LECANIUM longulum.
POLIANTHES (Amaryllidaceae).
LECANIUM oleae.
ASPIDIOTUS lataniae.
POLYALTHIA (Anonaceae).
ASPIDIOTUS orientalis.
POLYGONUM (Polygonaceae).
MARGARODES polonicus.
CHIONASPIS polygoni.
ASPIDIOTUS hederae.
POLYPODIUM (Filices).
LECANIUM hesperidum.
CHIONASPIS dilatata.
POMADERRIS (Rhamnaceae).
LECANIODIASPIS atherospermae.
ASPIDIOTUS subfervens.
LEPIDOSAPHES citricola.
POPULUS (Salicaceae) 'Poplar.'
ERIOCOCCUS borealis.
LECANIUM capreae, tiliae, nigrofasciatum, coryli, corni, ciliatum, zebrinum.
PULVINARIA occidentalis, tremulae, betulae, vitis.
CEROPLASTES rusci.
DIASPIS pentagona.
CHIONASPIS longiloba, ortholobis, salicis, salicis-nigrae, micropori, africana.
LEUCASPIS kermanensis.
FIORINIA africana.
ASPIDIOTUS ostreaeformis, perniciosus, camelliae, popularum, transcaspiensis.
LEPIDOSAPHES ulmi.
'POTATO' (Solanaceae).
PSEUDOCOCCUS affinis, solani.
LECANIUM tolucanum.
POTENTILLA (Rosaceae).
ASTEROLECANIUM fimbriatum.
PHENACOCCUS comari.
LECANIUM pulchrum.
POTHOS (Araceae).
LECANIUM marsupiale.
ASPIDIOTUS pothi.
POUZOLZIA (Urticaceae).
CEROPLASTES ceriferus.
PRASIUM (Labiatae).
ASTEROLECANIUM fimbriatum.
PRINOS (Aquifoliaceae).
PULVINARIA cockerelli.
LICHTENSIA viburni.
PRITCHARDIA (Palmaceae).
LECANIUM hesperidum.
CEROPLASTES rusci.
HEMICHIONASPIS aspidistrae.
LEUCASPIS cockerelli.
ASPIDIOTUS cyanophylli.
ISCHNASPIS filiformis.
PROSOPIS (Leguminosae).
PALAEOCOCCUS mexicanus, rosae.
ICERYA rileyi.
OPISTHOSCELIS prosopidis.
LECANIODIASPIS prosopidis.
ERIOCOCCUS quercus-toumeyi.
PSEUDOCOCCUS prosopidis, virgatus-farinosus.
TACHARDIA fulgens, lacca.
LECANIUM mirabile.
DIASPIS arizonica, townsendi.
ASPIDIOTUS candidulus.
XEROPHILASPIS prosopidis.
PROSTANTHERA (Labiatae).
CHIONASPIS eugeniae.
PRUNUS (Rosaceae).
CEROCOCCUS koebelei.
PSEUDOCOCCUS longispinus.
PHENACOCCUS aceris.
LECANIUM hoferi, armeniacum, capreae, cerasi, cerasifex, cockerelli, guignardi, juglandifex, juglandis,

PRUNUS (Rosaceae)—*cont.*
persicae, prunastri, pruinosum, rugosum, tiliae, variegatum, vini, oleae, padi, kunoensis, nigrofasciatum, coryli, bituberculatum, corni, hemisphaericum, hesperidum.
PULVINARIA amygdali, mammeae, occidentalis, pruni, psidii, betulae.
DIASPIS santali, pentagona.
CHIONASPIS lintneri.
EPIDIASPIS piricola, lepèrei.
ASPIDIOTUS forbesi, hederae, howardi, juglansregiae, dictyospermi, juglansregiae-pruni, ostreaeformis, perniciosus, aurantii, alni, pyri.
PARLATORIA theae, proteus, oleae, calianthina.
LEPIDOSAPHES ulmi.

PSEUDOTSUGA (Coniferae).
PHYSOKERMES taxifoliae.
ASPIDIOTUS ehrhorni.

PSIDIUM (Myrtaceae) 'Guava.'
ICERYA seychellarum, montserratensis, sulphurea.
PSEUDOCOCCUS longispinus, virgatus, citri, nipae.
PHENACOCCUS mangiferae, gossypii-psidiarum.
LECANIUM nitens, acuminatum, longulum, viride, depressum, nigrum, discoides, hemisphaericum, oleae, psidii, signatum, setigerum.
PULVINARIA cupaniae, ficus, psidii, africana.
PROTOPULVINARIA pyriformis.
CEROPLASTES campinensis, floridensis, grandis, psidii, vinsonii, singularis, destructor, vinsonioides.
VINSONIA stellifera.
CARDIOCOCCUS umbonatus.
CHIONASPIS eugeniae, megaloba.
PSEUDOPARLATORIA parlatorioides.
ASPIDIOTUS ficus, cyanophylli, cydoniae, rossi, lataniae, aurantii, translucens, camelliae, destructor, transparens.
LEPIDOSAPHES pallida.

PSYCHOTRIA (Rubiaceae).
LECANIUM hesperidum, piperis, marginatum.
CEROPLASTES rubens.
AONIDIA cornigera, spatulata.
PARLATORIA mytilaspiformis.

PTELEA (Rutaceae).
ASPIDIOTUS perniciosus, ulmi.

PTERIS (Filices).
ERIOCOCCUS insignis.

PTEROCARYA (Juglandaceae).
PHENACOCCUS aceris.

PTEROSPERMUM (Sterculiaceae).
LECANIUM tessellatum.

PTYCHOSPERMA (Palmaceae).
CEROPLASTES rubens.

PUERARIA (Leguminosae).
DIASPIS pentagona.

PUNICA (Punicaceae) 'Pomegranate.'
PSEUDOCOCCUS crotonis.
LECANIUM oleae.
CEROPLASTES floridensis, rusci.
ASPIDIOTUS cydoniae, orientalis, rossi, cydoniae-punicae.

PUTORIA (Rubiaceae).
ASPIDIOTUS hederae.

PYRUS (Rosaceae) 'Pear,' 'Apple,' etc.
PSEUDOCOCCUS bakeri, capensis.
PHENACOCCUS aceris.
FONSCOLOMBIA fraxini.
LECANIUM hoferi, armeniacum, capreae, cerasifex, cockerelli, corni, pruinosum, pyri, rugosum, tiliae, vini, oleae, glandi, bituberculatum, variegatum, kunoensis, nigrofasciatum, coryli, persicae.
PULVINARIA innumerabilis, amygdali, occidentalis, betulae.
CEROPLASTES rubens, rusci.
DIASPIS pyri, santalis, rosae, squamosa.
CHIONASPIS furfurus, salicis.
EPIDIASPIS piricoca, lepèrei.
LEUCASPIS japonica.
ASPIDIOTUS ancylus, forbesi, juglansregiae, ostreaeformis, pyri, perniciosus, camelliae, aurantii, tenebricosus, fuscus, africanus, pectinatus, ancylus-latilobis, lataniae.
PARLATORIA pergandei, proteus, calianthina, chinensis, pyri, oleae.
LEPIDOSAPHES ulmi, flava-hawaiensis.